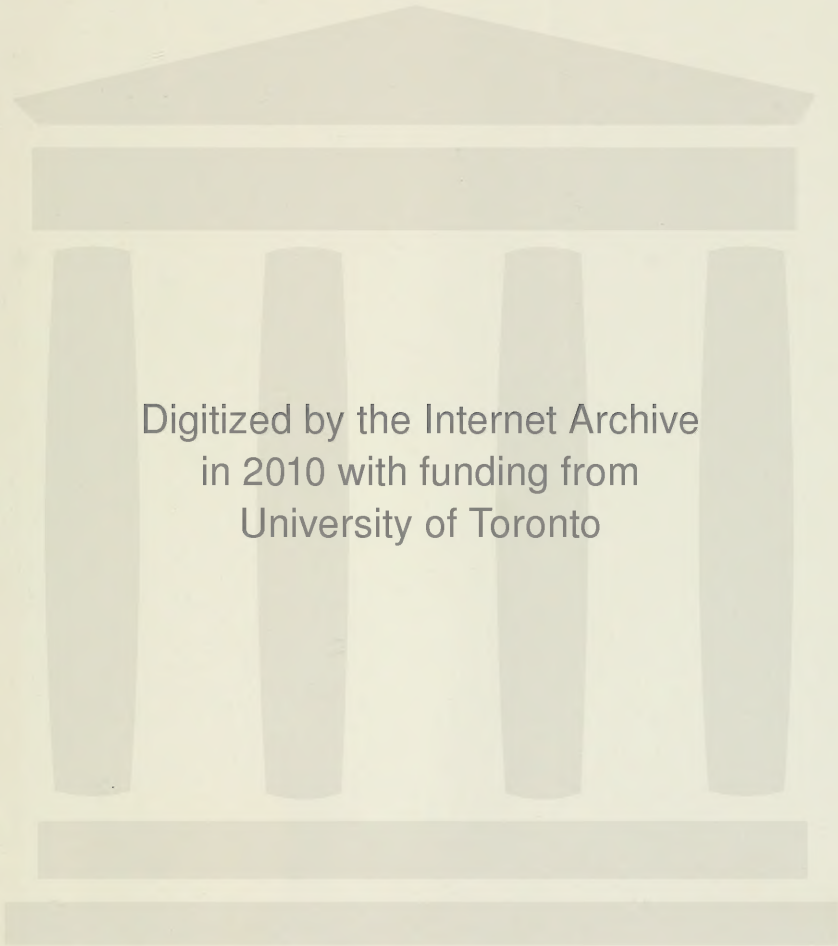

Digitized by the Internet Archive
in 2010 with funding from
University of Toronto

http://www.archive.org/details/chemicalengineer02newy

Tech
Chemical
Engineering

ELECTROCHEMICAL INDUSTRY

A Monthly Review of Electrochemistry and Electrometallurgy

VOLUME II

From January to December 1904

NEW YORK:
ELECTROCHEMICAL PUBLISHING CO.

436827
3. 7. 45

TN
1
C45
v.2

INDEX TO VOLUME II.

GENERAL ALPHABETICAL INDEX.

*Entries from the Synopsis of Articles in Other Journals are indicated by S. (Synopsis); from the Analysis of Current Electrochemical United States Patents by A. (Analysis); from the Digest of Electrochemical United States Patents Prior to July, 1902, by D. (Digest); from Recent Metallurgical Patents by M. (Mettallurgy); Illustrated articles are indicated by *.*

A

ABBE ENGINEERING CO..... 433
Accumulators. Regenerative steam. Deminge. (S.) 502
Acetic acid by electrolysis. (D.)..... 80
Acetic acid anhydride. Production. Winteler 340
Acetylene. Central stations. (S.) 32
——Compressing 143
——Oxygen burner. (S.) 32
Achroodextrin and alcohol..... 74
Acid-proof rubber goods..... 48
Acid pumps. American Hard Rubber Co. *209
Acid-resisting bricks *42
Acids. Lead-lined valve for handling. Schutte & Koerting Co..... *472
Alcohol. From wood. Buchner. (D.).. 124
——and achroodextrin 74
——Internal revenue tax. Schweitzer.... 448
Alkali. Electrolytic production of caustic. (See Sodium chloride, electrolysis.)
Alkalies chlorates, bromates, iodates by electrolysis. Kretzschmar. (S.).. 460
Alkaline metals and salts. Production of. J. W. Richards 5
Allis-Chalmers Co. Exhibit 377
ALLOYS:
——Imperfect equilibrium in. Osmond. (S.) 247
——Magnetic from non-magnetic metals. Hadfield. (S.) 429
——Study of. Shepherd. (S.)..... 502
——Aluminium and calcium. Meslans. (M.) 367
——Copper and arsenic. Hiorns..... 170
——Copper and zinc. Wheatley. (M.)... 367
——Copper and zinc. Shepherd. (S.)..... 372
——Lead and tin. Sackur..... 315
—— Peetz. (S.) 501
——Manganese and copper. (S.)..... 247
Alpha-naphthylamin from alpha-nitronaphthalin. Buchner. (D.)..... 124
Alpha-nitronaphthalin reduced to alpha-naphthalin. Buchner. (D.)..... 124
Alternating currents. Effect of frequency in electrochemical work..... 337
——Electrolysis of water. Van Naeme and Graefenberg. (S.) 245
——Converted into direct with aluminium electrode. (See Rectifier, Electrolytic.)
ALUMINIUM:
——from molten electrolytes. Higgs, Farmer, Gratzel, Heroult, Hall, Bradley, Edison, Emme. (D.)..... 166
—— Bernard, J. B. Hall, Case. (D.).. 210
—— Waldo and Gooch, Schwahn, Blackmore, Hoopes. (D.)..... 254
—— Gin. Bennie 128
—— Gin. (A.) 323
—— Fusion pot. Hunt. (D.)..... 518
—— Reduction pot. Dickey. (D.).... 518
——Alloys and sulphide. Production. Onda. (A.) *282
——Manufacture without electrolysis. Ruebel. (M.) 429
——Hydrate from bauxite. Roberts. (D.) 123
——New source of. Pool.....477, 487
——from ethyl bromide solutions. Patten. 413, 501
——State of industry 6
——in 1903. Struthers. (S.)..... 458
——in Italy 427
——and sodium or potassium double chlorides. Purification by electrolysis. Castner. (D.) 434
——Alloy. Kneppel. (M.) 235
—— Anderson. (M.) 508
—— with calcium. Meslans. (M.).... 367
—— with phosphorus. Meteorit..... 123
——Anode for rectifying alternating currents. See Rectifier, Electrolytic and Condenser Electrolytic. .....
——Anode film. Dimensions. Mott..... *269
—— Electrical properties. Mott *352
—— Colloidal precipitation. Mott....436, 444
——Corrosion and prevention. Mott..... *129
——Electrical conductor. Kershaw. (A.). 36
—— Buck 416
——Electrolytic condenser. Zimmerman.. 182
——Microstructure of cast..... *49
——Plating upon. Burgess and Hambuechen 81, 85
——Reducing agent. (See Aluminothermics.)
——Soldering. (S.) 115
—— Millett. (S.) 502
—— Flux. Ellis. (M.)..... 291
——Uses in textile industries..... 293
——Welding. Cowper-Coles.....31, 84
Aluminothermics. Production of pure metals free from carbon. Goldschmidt 145
——Analysis and tests 165
——Goldschmidt paper 404
Amalgams of sodium and potassium. Action on aqueous solutions. Fernekes 67
——Smith. (S.) 201
——Fernekes. (S.) 501
AMERICAN ELECTROCHEMICAL SOCIETY:
——4, 74, 85, 198, 250, 293, 300, 328, 338, 363, 396
——Election. Carhart 119
—— Reed 36
—— Richards 74
——St. Louis meeting *397
——Washington meeting.....125, 128, 167, *173
—— Banquet in Washington..... 174
——Madison section 161, 478
——New York section. Meeting report.. 64
——Philadelphia section..74, 95, 148, 250, 470, 478
American Hard Rubber Co. Acid pumps *209
——Exhibit *377
American Institute Elerical Engineers. 220, 224, 300
American Institute Mining Engineers. 231, 330, 470
American Lava Co..... 516
American Slate Co..... 473
American Vacuum Drying Machine Co.. *76
Amido-beta-naphtol from orange. II. Buchner. (D.) 210
Amines from nitro compounds. Buchner. (D.) 124
——(A.) 284
Ampere-hour efficiency 212
Anaconda. Palmer 461
ANALYSIS:
——Blow pipe. Measurement of gold and silver buttons. Richards..... *208
——Electrolytic. Copper. Richards and Bisbee. (S.) 289
—— Gold. Perkin and Prebble. (S.). 159
—— Nickel and copper. Browne..... *14
—— Manganese. Koester. (S.)..... 371
—— General. Hollard. (S.)..... 116
—— Revolving cathodes. (S.) 116
—— Medway. (S.) 427
—— Amberg. (S.) 289
——Carbon and phosphorus in steel. Iron and Steel Institute. (S.).... 503
——Molybdenum in steel. Cruser and Miller. (S.) 462
——Sulphur in iron. Ford and Willey. (S.) 462
——Quantitative. Miller. (S.) 116
Aniline from nitrobenzene. Buchner. (D.) 124
——(A.) 284
Aniline chloride from nitrobenzene. Buchner. (D.) 124
Anodes. Artificial graphite. Collins.... *279
——Construction. Blackman. (A.)..... 285
——for electrolysis of molten compounds. Heroult. (D.) 517
——Hook. Cann. (A.) 34
Anthracine. Electrolytic oxidation. Fontana and Perkin 249
Anthraquinone from anthracine. Fontana and Perkins 249
Anti-friction metal. (S.) 69
Antimony sulphide by electrolysis. Richards and Koepper. (D.)..... 44
Apatite for making manure. Palmaer.... 470
Applied Electrochemistry. Some aspects of. Johnson 414
Arc. Study of. Weedon 183
——Child 416
——Discharges through air. Production of a gas for purifying cereals. Alsop. (A.) 242, 243
Argon 12
Armor plate metal. Direct casting and hardening. Everette. (A.)..... 508
Arrhenius, biography. (S.) 160
Arsenic and the e. m. f. in copper electrolysis. Wickes. 137
——Johnson 207
Arsenic and copper alloys. Hiorns..... 170
Arsenic removed from ores. Eames. (D.) 474
Atmospheric Products Co. 250
Atoms. Dielectic capacity. Sutherland. (S.) 202
——Radioactive. Reuterdahl 250
——Structure of 125
—— Thomson. (S.) 156
——Compressible and electrochemistry. Richards 397
——and hylotropy. Ostwald 361
——and ions. Reality 436, 498
Attraction between molecules. Mills. (S.) 370
Azo dyes. Preparation. Loeb. (A.).... 284

B

BAKER & CO. Exhibit..... *331
Baking carbon bars. Price. (A.)..... 111
Bartlett & Snow Co., C. O. Exhibit..... 383
Batteries. Thermochemical theory of. Lorenz 15
——Flexible conductor for. Kennedy. (A.) 113
Battery. (See also Storage Battery, Primary Battery, Standard Cell, Carbon Cell, Concentration Cell, Gas Battery.)
Bausch & Lomb Optical Co. Exhibit.... 383
Bauxite in India. Pool..... 487
——in 1903. (S.) 468
Bennett & O'Connell Co. Electroplating dynamos *472
Benzalchloride 341
Benzene series. Electrolytic oxidation of hydrocarbons. Perkin 487
Benzine fires. Prevention. Just. (S.).. 203
Benzylamin from phenylnitromethane. Buchner. (D.) 124
Bertuch & Co., Fred'k 333
Beryllium 12
Bicycle frames. Removing brass from. Burgess *8
Bismuth. Becker. (S.)..... 319
Bitumen in insulating compounds. Sutherland 4, 69
Blackwell Sons & Co., Geo. G..... 333
——Deoxidizer for steel..... 295
BLAST FURNACE:
——Dry-air blast. Gayley. (S.)..... 503
——Extracting moisture from air. Gayley. (M.) 469
——Theory. Schenck. (S.) 322
——Thermal efficiency. Foster. (S.)..... 289
——Charging apparatus. Schneider. (M.) 509
——Top construction. Hamfeld. (M.).. 236
——Latto & Callan. Dust collector. (M.) 469
——with magnetizing coils. Hay. (D.).. 434
——Waste gases, cleaning. Hardie. (A.) 425
—— McKee. (M.) 509
——for treating by-products of cyanide works. Dixon and Torrente 219
——Slag or cinder for bricks. Uehling. (M.) 291
Bleaching. Electrolytic. Vogelsang. (A.) *205

Bleaching. Ruthenburg. (A.) 70
Bleaching powder from electrolytic chlorine. Winteler 339
——(See also Sodium chloride, electrolysis of.)
Blue vitriol production in Kansas. (S.).. 160
Bogue, C. J. Dynamos for electrolytic work 43
Book Reviews:
——Art of Illumination. By Bell..... 75
——Storage Battery Engineering. By Lyndon 120
——Electrolytic Preparations. By Elbs-Hutton. 208
——Iron, Steel and Other Alloys. By Howe 120
——The Proceedings of the Chemical and Metallurgical Society of South Africa, Vol. II. 75
——Ready Reference Tables. By Hering. 329
——Trans. Am. Electrochem. Soc., Vol. V. 330
——The Electric Furnace. By Moissan-Lenher 330
——Analytical Chemistry. By Treadwell. 331
——Alternating Currents. By Hanchett.. 373
——The Alternating-Current Transformer. By Baum 373
——Quantitative Chemical Analysis by Electrolysis. By Classen 431
——Electrical Influence Machines. By Gray 470
——Monographs on Applied Electrochemistry, vol. I., III. By Engelhardt-Richards 510
——Jahrbuch der Electrochemie, 1903. By Danneel 510
——Chemiker Kalender, 1904. By Biedermann 251
——Institut fuer Elekrometallurgie in Aachen. By Borchers 36
——Metalle. By Neumann 251
——Electrochemie auf der Ausstellung in Duesseldorf. By Danneel 76
——Elektrolytische Raffination des Kupfers. By Ulke-Engelhardt..... 252
——Kalender für Elektrochemiker. By Neuburger 119
——Soda Caustica. By F. Villani..... 251
Brass. Removing from iron by electrolysis *8
Bricks. Flue dust and fire ores. Bennett. (S.) 462
Bricks and rings, acid resisting for packing Glover and Gay-Lussac towers. *42
Brick burning. Eldred process..... 498
Briquetting concentrates. Rouse. (M.).. 235
——Louis. (S.) 462
Briquetting fuel. Fulton. (S.)..... 462
Bromides of alkalies. Electrolysis. Kretzschmar. (S.) 460
Brominated indigo. Schmidt and Mueller. (A.) 364
Bromine. Potential. Mott *177
Bromoform from acetone. Mueller and Loeb. (S.)..... 288
Brushes from carbon. Le Valley Vitæ Co. 208
Buffalo Forge Co., exhausters..... *332
——Exhibit 378
Burgess, C. F., portrait 190
Bushings of graphite..... *279

C

CADMIUM. Electrodeposition. (S.) ... 200
Cadmium cell. (See Weston cell.)
Cadmium-yellow by electrolysis. Richards and Roepper. (D.) 44
Cadmium in spelter. (S.)..... 462
Caesium 12
Calcites. (S.) 203
Calcium. Manufacture. Rathnau 276
——from fused calcium chloride. Stockem. (S.) 156
——and aluminium alloy. Meslans. (M.) 367
——as pyrochemical agent 178
——for removing carbon from metals and alloys. (M.) 468
Calcium Carbide 473
——Plants. (S.) 115
——by electrolysis. Moissan. (S.)..... 199
——as electrode. Griffin. (A.)..... 206
——(See also Furnace, Electric. Calcium carbide.)
Calomel electrode. Ley and Heimbucher. (S.) 245
Canadian Copper Co..... 425
Capacity, dielectric, of atoms. Sutherland (S.) 202
Capillary electrometer. Burgess *194
Carbon:
——as refractory material 443
——for temperature tests in electric furnace. FitzGerald 415
——Articles made in electric furnace. Acheson. (A.) 108
——Bars baked. Price. (A.)..... 111
——Brushes. Le Valley Vitæ Co..... 208
——Cell. Theory of. Lorenz 15
—— Reed 18
—— Theory. Haber and Bruner....401, 428
—— Jones'. By Reed 18
—— (A.) 326
—— Noble and Anderson's. (A.)..... 242
—— Reid's. By Reed 18
—— (S.) *30
—— (A.) *242
——Chlorides and silicon made in electric furnace. Machalske. (A.) 39
——Compound, containing molybdenum. Moissan 470
——Electrodes. Baking 7
—— for metallen electrolytes. Heroult. (D.) 474
—— Construction. Atkins. (A.) *150
—— Construction. Acker. (A.)..... *34
—— See also Graphite.
——Granular in resistance furnace. Fitzgerald *490
——ions. Existence of. Lorenz 17
——Monoxide. Production of pure. Hutton and Petavel *142
——Silicide. See Carborundum.
Carbonate. Potassium-magnesium. Auerbach. (S.) 160
Carborundum. Analysis 443
——Fire-sand 440
——Refractory material 442
——and zinc. Simultaneous production. Dorsemagen 7
——Carborundum Co. Exhibit *374
Carbureted air for lighting 121
Card index to electrochemistry. Voege. 187, 313
Carhart, H. S. Portrait *176
Carlin tube. Electrode connections..... 57
Carnegie, A. Bessemer medalist..... 438
Cartridge. Explosive electrolytic. (A.).. 286
Case School of Applied Science..... 161
Castings repaired by thermit process. See Aluminium.
Castner Electrolytic Alkali Co..... 295
Castner Memorial Tablet. (S.)..... 249
Catalysis and electrolysis..... 336
——Ostwald 393
——Examples. Thatcher *452
Catalytic action of cyanogen ions. Bredig 361
Cathode rays. Chemistry. Mose..... *362
Caustic alkali and copper sulphate. Palaa and Cotta. (D.) 80
Caustic alkali. See also Alkali and Sodium Chloride. Electrolysis.
Caustic potash for electroplating..... 121
——See also Sodium Chloride. Electrolysis.
Caustic soda and chlorine plant. (S.).... 115
Caustic soda industry. Condition of. (S.) 115
Caustic and sulphuric acid by electrolysis of molten nitrates. Darling. (D.). 44
Caustic soda. See also sodium chloride, Electrolysis.
Cell for electrolysis of molten salts. Graham. (D.) 474
——Rogers. (D.) 474
——Rennerfelt. (D.) 474
——Case. (D.)..... 474
——Lyte. (D.) 517
Cellulose. Manufacture. Kellner. (A.).. 505
Cement kiln. Thermal efficiency. Richards. 159
——Burning. Eldred process 498
Centrifugal machine *43
Chain drive. Silent. Morse Chain Co.... *515
Chamber of Delegates, International Electrical Congress *419
Charcoal as refractory material..... 443
Chavant, C. H., & Co., Centrifugal machine *43
Chemical engineer, training. Herreshoff. 169, 171
——Sanders 292
——Ramsay 417
——Metallurgist 455
——Walker 478
"Chemical Engineer" 509
Chemical industries. How to promote them. Schweitzer 447
Chemistry. Mineral. Relation to other sciences. Moissan 438
——Laboratory course in industrial. Walker 478
Chloral. Production. Winteler 340
Chlorates. Preparation. Siemens & Halske. Mueller. (S.)..... 501
Chlorides of alkalies. Electrolysis. See Sodium Chloride. Electrolysis.
——of lead, silver, mercury made by electrolysis. Currie. (D.) 44
Chloride of lime from electrolytic chlorine. Winteler 339
—— See also Sodium Chloride. Electrolysis.
——of phosphorus from electrolytic chlorine. Winteler 340
——of potassium or sodium electrolysis. Compared. Winteler 391
——of sulphur from electrolytic chlorine. Winteler *339
Chlorination process. Greenawalt. By Perkins *24
Chlorine. Uses of electrolytic..... 335
—— Winteler *339
——in metallurgy. Swinburne 402
——Electrolytic for cellulose. Kellner. (A.) 505
——Liquid 143
——Lead and silver from molten electrolyte. Lyte. (D.) 518
——Potential. Mott *177
——and potassium or sodium carbonate from molten electrolyte. Hyte. (D.) 474
——See also Sodium Chloride. Electrolysis.
Chloroform. Production. Winteler 340
——from acetone. Teeple. (S.)..... 287
Chromic acid battery. Gardiner. (D.)... 44
——Regeneration. Hess. (D.) 80
Chromic acid solutions. Production and regeneration. Le Blanc and Reisenegger. (D.) 44
Chromium from chrome iron ore. Suchy and Tycketer. (A.) 34
——free from carbon. Goldschmidt..... 146
——Production of pure. Eaton. (M.)..... 235
Chromium hydroxide by electrolysis. Street. (D.) 80
Circuit breakers. Graphite contacts..... 280
Circulation of liquids. Dunton. (A.).... 239
——During electrolysis. Sand. (S.)..... 320
Clark cell. Wolf 174
Cleaning gas. Hardie. (A.)..... 425
Coke desulphurized. Nock. (D.)..... 434
Colloidal precipitation upon aluminium anode. Mott 444
——and valence 446
Colloids. Jordis 277
Color photograph 293
——by electrolysis. (S.) 69
Columbium 62
Combustion. Regulation. Eldred process. Ellis *495
Commission Canadian Electric Furnace. See Furnace. Electric. Iron and steel.
Commutation, sparkless of dynamos. Browne *86
——Mailloux 131
Composite metal roll. Reed. (A.)..... 36
Composition and resolution of voltages. Richards 95, 178
Compression of gases. Hutton and Petavel *143
Compressible atoms and electrochemistry. Richards 397
Concentrated solutions. Molecular depression of freezing point. Jones and Getman. (S.) 158
Concentrates briquetting. Rouse. (M.).. 235
——Louis. (S.) 462
Concentration. Magnetic. Louis. (S.). 287
——Fine ores. Payne. (S.)..... 287
——King. (A.) 327
Concentration cells. Theory 100
Concentration changes in lead cell and oxygen—lift cell..... 255
——Determined during electrolysis. Sand 486
Concentrations. Very small ionic. Haber. (S.) 320
——Bodlaender, Abegg, Danneel, Haber. (S.) 501
Concilium bibliographicum 315
Condenser. Electrolytic. Zimmerman.... 182
Conduction. Electrolytic. Theory. Richards 411
Conductivity and ionic mobilities. Kohlrausch and Grueneisen. (S.)..... 461
——Electric, near critical point. Kraus. (S.) 201
——Electric, of solutions at high temperatures. Noyes and Coolidge. (S.). 201
——of electrolytes measured. Burgess.... *195
——Measurements of copper electrolytes. Addicks *306
——Molecular. Reed 179
Congress. International Electric, in St. Louis..48, *84, 214, 258, 295, 300, 373, *396
——Chamber of Delegates *419
——Electrochemical features.....385, *397
Congress. International, of Arts and Science 351, 438
Congress. International Engineering.... 300
Connections of electrodes for electrolytic vats. Dessauer 57
Connector for electrodes. Fritchle. (A.). 425
Contacts of graphite 280
Contact losses in copper refinery tanks. Hutchinson 14
——Magnus 74
Contact processes and electrolysis 336
——for sulphuric acid..... 347
Converter. Bessemer. Treating copper matte. Baggaley. (M.) 328
——Extracting moisture from air. Gayley. (M.) 469
Converting alternating into direct current. See Rectifier. Electrolytic.
Copper:
——Alloys with arsenic. Hiorns..... 170
—— with cuprous oxide. Microstructure 82
—— Hofman, Green, Yerxa..... *87
—— Addicks *224
—— with manganese. (S.)..... 247
—— with zinc. Shepherd. (S.)..... 372
—— Wheatley. (M.) 367
——Analysis. Browne *14
—— Richards and Bisbee. (S.)..... 289
—— Estimating oxygen in.....82, *87, 224
——Anodes. Reaction at. Fischer. (S.). 320
——Coating on iron. Gaudin, Mignon, Rouart. (D.) 431
——Compounds. Dissolving action of ferric sulphate. Thompson *225
——Cyanide. Treadwell and Girsewald. (S.) 248
——Electrodeposition of. Cowper-Coles. (S.) 27
—— Rapid. (S.) 67
——Electrolyte. Rapid measurement of conductivity. Addicks *306
——Foundry practice. Reardon. (S.).... 247
——Microstructure *50, 82, *87, 224

- Production from ores..... 213
- Metallurgy. Ingalls. (S.)..... 462
- Matting. Use of waste gases. Herman. (M.)..... 468
— Effect of roasting on subsequent leaching with sulphuric acid or ferric sulphate. Thompson. 228
— Matte. Bessemer converter. Baggaley. (M.)..... 328
— Smelting. Baggaley & Allen. (M.)..... 367
— Electric smelting. Vattier. (S.). 27
— from molten electrolytes. Guillaume. (D.)..... 518
— Extraction by wet process. Ball. (S.)..... 462
- Ions..... *272
— Siemens process. Thompson.. *225
— Cyanide process. Porter. (M.) 235
— Treatment with ferric sulphate. Thomas. (S.)..... 155
— Precipitation of cement copper by iron. Jones..... *233
- from mixed ores. Clark. (M.) 235
— Envelop for anode with ferrous sulphate solution. Laszczyuski. (A.)..... 238
— Extraction from comminuted mineral mixtures. Le Sueur. (A.)..... 151
— Deposition in Siemens' process. Conditions of spongy deposit. Thompson..... 228
— Anaconda. Palmer. (S.)..... 461
— Mansfield. (S.)..... 288
— Refining.
— Pioneer refinery in United States, Balbach works..... *302
— Rapid measurement of conductivity of electrolyte. Addicks..... *306
— Study of the stages in. Hofman, Green, Yerxa..... *87, 224
— Economic balance in. Addicks.... 180
— Contact resistances and current leakages. Hutchinson..... 14
- Magnus..... 74
— Arrangement of electrodes. Schwarz. (A.)..... 239
— Arsenic in. Wickes..... 137
— Johnson..... 207
— Non-uniformity of cathode copper. (S.)..... 245
— Refining by electric current passed through molten metal. Wall. (D.)..... 434
—Sampling plates of blister-copper. Baggaley. (M.)..... 367
—Sulphate production in Kansas. (S.).. 160
—Sulphate. Electrolysis. Foerster and Coffetti. (S.)..... 460
—Sulphate and caustic alkali. Palas and Cotta. (D.)..... 80
—Sulphate in viniculture..... 161
Voltameter. Adams and Hall..... 182
—Wire. Electrolytic production. (S.).. 115
Corpuscular theory. See Electrons.
Corrosion of iron and steel. Prevention. Cowper-Coles. (S.)..... 322
—of radiators, prevented by zinc. Kinnear. (A.)..... 153
Corubin..... 403
Corundum from aluminothermic reaction..... 405
Cowles Electric Smelting & Aluminium Co. Silicon-copper..... 121
Crocker Wheeler Co.....165, 296
—Exhibit..... *380
Crucibles of artificial graphite..... *345
—of corubin. Goldschmidt..... 405
Crucible furnace. Speirs. (M.)..... 328
Cupola with magnetizing coils. Hay. (D.) 434
Cyanamide salts. Production. Erlwein. (A.)..... 204
Cyanide. Copper. Treadwell and Girsewald. (S.)..... 248
Cyanide process. Limitations of. Durant. 107
—Increased scope. Porter. (M.)..... 235
—Byproducts of. Butters..... 54
— Dixon and Torrente..... 219
—See also Gold.
Cyanides made in electric furnace. Dankwardt. (A.)..... 69
Cyanogen. Recovery from the double salts of a cyanide solution. Davis. 187
Cyanogen ions. Catalytic action. Bredig. 361

D

DANIELL CELL and Gibbs-Helmholtz equation. Carhart..... 130
tion. Carhart..... 130
—as standard cell. Rossi. (S.)..... 246
Denver Fire Clay Co. Exhibit..... 383
Deoxidizer for steel. G. G. Blackwell Sons & Co..... 295
Dextrine from wood. Buchner. (D.).... 124
Diaphragms. Porous. Sadler..... 187
—Perkin..... 281, *370
—Characteristic features of. Tardy and Guye. (S.)..... 286
—(See also Sodiumchloride. Electrolysis with diaphragm cell.)
Diaphragm. Semi-permeable. Sebor. (S.) 289
Dichloracetic acid. Production. Winteler..... 341
Dielectric capacity of atoms. Sutherland. (S.)..... 202
Dielectric constants. Schlundt. (S.)..... 158
of solvents and solutions. Eggert. (S.)..... 116
Dielectric Mfg. Co. Insulating materials. 165
Diethyl-ether. Production. Benjamin. (D.)..... 80
Discharges through air and gases. Pauling. (A.)..... 243
Production of a gas for purifying cereals. Alsop. (A.)..... 242, 243
See also Nitrogen. Fixation of atmospheric, and ozone generators.
Dissociation phenomena at high temperatures. Loeb..... 256
Theory. Traube. (S.)..... 350
—Thermochemistry of electrolytic. Reed 65
Doremus, C. A..... 434
Drilling by electrolysis. Cowper-Coles. (S.)..... 28
Drive. Silent chain. Morse Chain Co... *515
Drown, T. M. Obituary..... 517
Dry cell. Construction. Gill. (A.)..... 71
—of Leclanche type. Marschall..... 63
—Swan and Rose. (A.)..... 207
—Schauli and Lowenstein. (A.)..... 72
Drying in vacuum. American Vacuum Drying Machine Co..... *76
Dust arresters. Newton, Diggle, Watson. (M.)..... 291
Dyes. Azo. Preparation. Loeb. (A.)... 284
Dynamo. What ailed the dynamo? Browne..... *86
—Mailloux..... 131
Dynamos for electroplating and electrolytic work. C. J. Bogue..... 13
—Bennett & O'Connell Co..... *472
—General Electric Co..... *77

E

EARTHS. Rare..... 61
Edison. Biographical sketch..... *103
—See also Storage Battery.
Edison Storage Battery Co. Exhibit..... 375
Efficiency. Ampere hour-, watt hour-, financial..... 212
—Energy, transformation and calculation.. 2
—Thermal of blast furnace. Foster. (S.)..... 289
—Thermal of cement kiln. Richards. (S.)..... 159
Eimer & Amend. Exhibit..... 383
Eldred process. Ellis..... 295
Electric Appliance Co. Electrolytic rectifier..... *76
—Electrolytic interrupter..... *252
Electric Club Journal..... 48
Electric Controller & Supply Co. Exhibit 382
Electric furnace. See Furnace. Electric.
Electric Smelting & Aluminium Co..... 473
Electric Storage Battery Co. Exhibit.... 375
Electric Time Co. Electrically operated whistle..... *332
Electricity direct from carbon. See Carbon Cell.
Electricity and matter. Lodge..... 315
Electrochemist. Training..... *189. *264, 455
Electrochemistry. Some aspects of applied. Johnson..... 414
Electrochemical equivalent of silver. van Dijk and Kunst. (S.)..... 117
Electrochemical industries Present status of. J. W. Richards..... 5
—Lectures. Crocker and Arendt. (S.). 115
Electrochemical notation..... 251
Electrochemical series of metals. Kahlenberg..... *402
Electrochemistry. Advances in. Blount. (S.)..... 154
—Continuous advance. Richards..... 177
—Progress of..... 1
—Revolutionary character..... 292
—Early theories. By Neuburger. (S.). 29
Electrolyte:
—Auxiliary for tests. Liagre. (S.)..... 428
- of carbon. Acker. (A.)..... *34
- Atkins. (A.)..... *150
— Baking..... 7
— for molten electrolytes. Heroult. (D.)..... 474
— Heroult. Lyte. (D.)..... 517
—Graphite. Collins..... *277
—Connections. Dessauer..... 57
Blackman. (A.)..... 70
Fritchle. (A.)..... 425
—Hard, porous, pure, insoluble in alkaline solutions. Poerske and Wedekind. (A.)..... 286
- Hook. Camp. (A.)..... 34
—Mercury. Construction. Winsmore. (S.)..... *127
—Standard. Construction. Danneel. (S.)..... 127
- Potential. Johnson..... *87
- Settingen..... 58
— Gahl..... 96
— Measurement in stationary liquids. Sand..... 486
- Supports. Burgess..... *193
Electrogalvanizing. Grabrau. (S.)..... 28
Electrolysis according to the energonic hypothesis. Reuterdahl..... 253
—and catalysis..... 336
— Ostwald..... 393
—for drilling and slotting. Cowper-Coles. (S.)..... 28
—Thin-film, applied to printing. Darling..... 170
—See also the various substances which are electrolyzed or produced by electrolysis.
Electrolyte resistance measurements. Burgess..... *195
Addicks..... *305
Electrolytic analysis. Hollard. (S.)..... 116
—See also Analysis.
Electrolytic conduction. Theory. Richards..... 111
Electrolytic dissociation. Thermochemistry. Reed..... 65
Traube. (S.)..... 350
Electrolytic extraction of gold. Feldkamp. (A.)..... *112
—Formation of periodates. Mueller. (S.)..... 114
—Production of copper wire. (S.)..... 115
—Production of oxides and hydroxides of metals. Hunt. (A.)..... 112
—Purification of juices. Kollrepp and Wohl. (A.)..... 113
—Purification of liquids. Kartzmark. (A.)..... 114
—Refining. See Refining and also the
—Separation. See the different metals, different metals.
—Stripping of metals. Burgess..... *8
Electrometer. Capillary. Burgess..... *194
Electromotive force. Thermochemical calculation. Lorenz..... 15
—Daniell cell. Carhart..... 130
—Composite reaction. Richards.....95, 178
Electronic theory..... 416
—Structure of atom. Thomson. (S.).125, 156
—Theory of electrode voltage. Gahl.... 96
Electroplating. See Plating.
Electrotyping. Molding case. Welsh. (A.)..... 114
Elements. Rare. Lenher..... 61
Energonic hypothesis. El c rolysis according to. Reuterdahl..... 250
Energy of ions. Parsons..... 182
Engelhardt, Chas. Pyrometer..... *472
Engineer, Chemical. Training. Herreshoff..... 171
—Sanders..... 292
—Ramsay..... 417
—Walker..... 478
—Metallurgist..... 455
Equilibrium. Imperfect in alloys. Osmond. (S.)..... 247
Ethyl bromide solutions. Aluminium from. Patten.....418, 501
Ethyl chloride..... 143
Ethylene chloride..... 341
Ethylene. Production. Hutton and Petanel..... 142
Exhaust steam from engines utilized. Demings. (S.)..... 502
Explosive cartridge by electrolysis. (A.) 286
Explosives, Chemistry of. (S.)..... 69
Extracts of essential oil by electricity. Burton. (A.)..... 327

F

FABRICS. Coating with metals. Keppler. (A.)..... 34
Faraday Society.....4, 84, 170, 281, 486, 509
Fats purified by electrolysis. Schwahn. (D.)..... 43
Ferric sulphate. Dissolving action on copper compounds. Thompson... 225
—Dissolving action on iron oxide. Thompson..... 228
—Reduced by sulphurous oxide. Thompson..... 228
—for treating copper ores. Thomas. (S.)..... 155
FERRO-ALLOYS:
- Manufacture in electric furnace. Scholl.....*339, 395, 449
—Manufacture, de Alzugaray (M.).. 430
- Free from carbon. Kuegelgen and Stewart. (M.)..... 468
- Rossi..... 65
—See also Furnace, Electric, Iron and Steel.
—Ferro-chromium. Scholl..... 450
—Ferromanganese. Production. Gin. (A.)..... *149
—Ferro-molybdenum..... 451
—Ferronickel, direct from pyrrhotite. Speeteldt. (S.)..... 153, 188, 207
—Ferrosilicon. Manufacture.....122, 318
- Scholl.....351, 395, 449
- Gin. (A.)..... *149
- from iron sulphide and quartz. Amberg. (S.)..... 199
- in reducing cast iron..... 122
- in manufacture of steel..... 122
Ferrosilicon explosions..... 84, 287
—Ferrotitanium. Box reaction. Goldschmidt..... 405
—Ferro-tungsten. Scholl..... 451
—Ferro-vanadium. Scholl..... 451
Ferrous sulphate electrolysis. Envelop for anode. Laszynski. (A.)..... 238
Ferrous sulphate, electrolytic oxidation of. Thompson..... *230
Fertilizers. Phosphate by electrolysis. Palmaer..... 470

Files. Cleaning clogged files by electrolysis. Burgess.... 10
Film. Thin-film electrolysis, applied to printing. Darling.... 170
Film on aluminum. See Aluminum anode film.
Filter and purifier for feed water. Dougherty. (A.).... *467
Filtering apparatus. Webb. (M.).... 431
Turner. (M.).... 431
Filter presses. Niles Tool Works.... 163
——in gold metallurgy. Pritchard. (S.). Ankeny. (M.).... 28
Finishing metal articles. Manning. (A.) 71
Firebrick for crucible furnace. (S.).... 218
Fire-proof wire, Heany's. Easton.... 161
Flame arcs between metallic electrodes. Weedon. 182
Flame regulation, Eldred process. Ellis. *495
Fluorine. Made by electrolysis. Meslans. (D.). 124
Potential. Mott.... *177
——Ions. Effect on formation of periodates. Mueller. (S.).... 501
—— Effect on formation of persulphates. Mueller. (S.).... 501
Flux for welding. Stout. (M.).... 235
Food problem. Sonheim.... 438
Foundry practice with copper. Reardon. (S.). 247
Franklin Institute.... 119
Freezing point. Molecular depressions in concentrated solutions. Jones and Getman. (S.).... 158
——Highly saturated salt solutions. Coppet. (S.).... 501
——Determinations in medicine. Schroeder. 362
Urine. Dreser.... 363
Frequency of alternating currents. Effect in electrochemical work.... 337
Friction. Internal for solutions. Madori. (S.). 371
Fuel briquettry. Fulton. (S.).... 462
Fuel economy. Kershaw. (S.).... 248
Furnace, Assayer's. Calkins. (M.).... 509
FURNACE, ELECTRIC:
——GENERAL CONSTRUCTION AND DESIGN:
—— Automatic control of temperature. Johnson. (A.) 324
Compensating terminal. Potter. (A.) 463
—— Construction, Arc. Imbert. (A.) 423
—— Conley. *424
—— Cowles. (A.). *238
Dicalf. (A.). 323
—— Franklin. (A.). *32
—— Guillaume. Arc and electrotysis. (D.). 518
—— Horry. (A.).236, *237, 364, *463, 464
Horry and Price. (A.).... 237
Price. (A.).... *237
Contardo. (A.).... 110
Cowles. (A.).... *108, 109
"The Pelton".... 516
—— Potter. *203
—— Stevens and Timmermann. (A.). 110
—— Wright. (S.).... 245
—— Dentists'. Pelton. (A.).... 238
—— Design.... 236
—— Development. Minet.... 281
—— Electrodes of artificial graphite. Collins. *277
—— General features in metallurgical applications. Richards. (S.). 198
General. Izart. (S.). 370
—— By Minet. (S.). 28
—— Granulated resistance material (Kryptol). Voelker. (A.)..... 463
—— Industries in 1903. Fitz Gerald.... 6
—— Laboratory. 29, 117
—— Melting point determinations. Day and Allen. (S.). 500
Metallurgy. Petavel.... 188
—— Principles of resistance, furnace design. Fitz Gerald.... *342
—— Refractory oxides, silicates, etc., as resistance material. Steinmetz. (A.). 504
—— Refractory material for lining. Fitz Gerald. *439
—— Materials for resistors in resistance furnaces. Fitz Gerald... *490
—— Temperature, regulation in.... 7
—— Testing temperature in. Fitz Gerald 415
Tube. Estey. Potter. (A.). 203
MISCELLANEOUS:
Aluminum alloys and sulphide. Onda. 282
Brick, pottery. Dickinson. (A.). 504
Calcium carbide (A.) 109, 169, 236, *237, 238, 323, 364, *463, 464.
Carbon articles. Asheson. (A.).. 108
Carbon bars baked. Price. (A.).. 111
Carbon chlorides and silicon. Mandabke. (A.) 23
Copper. Vattier. (S.).... 26
Cyanamide salts. Erlwein. (A.). 204
Cyanides and alkali metal. Dankwardt. (A.). 70
Cyanides. Dankwardt. (A.).... 69
Ferro-alloys.....65, *249, 395, 449
Ferromanganese. Gin. (A.).... 149
Ferronickel from pyrrhotite. Sjoestedt. *153, 188, 207
Ferrosilicon. Gin. (A.) *149
—— Scholl..... 351, 395, 449
Glass. (S.).... *244
Benjamin. (A.).... 283
Brown. (S.).... 409
Franklin. (A.).... *32
Kessmeir. (A.).... 32
Graphite from charcoal. Weckbecker. (S.).... *244
Iron and Steel.....6, 257
Bennie lecture.... *307
Canadian Commission..48, 198, 280, 329, *479, 475
Combination with open-hearth furnace for taking off the peak of the load. Richards 178
Cost. By Neumann. (S.) 319, 427, 488
Foundry practice.... *309
General. By Schneider. (S.). 459
General. By Minet. (S.).... *368
Miscellaneous.... 6, 7
Neuburger. (S.).... 199
Plant in Canada.... 391
Stansfield. (F.).... 318
Inventors:
Conley. (A.).... 424
Gin. By Bennie.... *20
Gin.....120, 464
Girod.... *309
Harmet. (A.).....110, *503
Heroult.....408, 481
Keller 120, *150, 280, *483
Kjellin.... 479
Minet-Neuburger. (S.).... *368
Ruthenburg. By Goldschmidt 315
Schneider induction. (A.).*323, *283
Magnesite bricks shrunk. Scott.
Fitz Gerald.... 454
Nickel. Becker. (S.).... 114
Silicon.... 7
Gin. (A.).... *111
Silicon and carbon chlorides. Mahalske. (A.).... 33
— Siloxicon.... 7
— Smelting matte, or sulphide, or sulph-arsenide ores. Danckwardt. (A.).... 109
— Vanadium and alloys. Gin. (A.) *324
— Zinc. Gin. (A.).... *457
— Blende treated for zinc, calcium carbide, carbon bicuiphide. (A.).... 32
Danckwardt. (A.).... 109
— De Laval. (A.).... *423
Salgues. (S.).... 499
FURNACE, METALLURGICAL:
— Allen. Roasting. (M.).... *368
—Arnold. Treatment of iron and steel before rolling. (M.).... 367
—Arnold. Reheating billets. (M.).... 469
—Atha. Recarburizing scrap steel. (M) 367
—Baggeley and Garretson. Utilizing heat of slag. (M.).... 236
—Bagley and Allen. Copper smelting. (M.). 367
— Bean. (M.).... 291
—Bray. Reheating plates. (M.).... 328
—Brown. Stack furnace for reduction. (M.). *50
— —Burrow. Puddling. (M.).... 508
—Cockell and Fish. Roasting and smelting. (M.).... *509
—Corcoran. Rabbles for roasting or calcining. (M.) 469
—Davis. Reversible door. (M.).... 236
—Gaines. Hot-blast apparatus. (M.).. 236
—Hirschmann. Heating slabs. (M.).. 328
Hofmann. Roasting. (M.).... *450
—Klopman. Detecting leaks in twyers, etc. (M.). 236
—Latto and Callan. Dust collector. (M.). 469
—McGee. Smelting. (M.).... 469
—Meyer. Roasting. (M.).... 291
O'Brien. Roasting. (M.).... 508
—Potter. Endwise-tilting. (M.).... 109
—Robinson. Refining. (M.).... 328
—Schneider. Charging apparatus. (M.) 509
—Shellaberger. Roasting. (M.).... 368
—Siemens. Regenerative gas furnace..236, 321
—Smiht. Crucible. (M.).... 469
Smyth. Roasting. (M.).... 291
—Southern. Melting metals. (M.).... 295
—Smith. Smelting. (M.).... 469
—Stewart. Gas seal. (M.).... 469
—Stromberg. Valve. (M.).... 469
—Wills. Iron ore. Oil fuel. (M.).... 235
—Wilson. Roasting. (M.).... 291
—Pan and blast, for treating by-products of cyanide works. Dixon and Torrente.... 219
—Feeding devices. (M.).... 469
See also the different metals and blast furnace
Fused salts. Electrolysis. Lorenz..... *412
See also the different substances.

G

GALLIUM 13
GAS:
——Preparation and compression of gases for experimental work. Hutton and Petavel. *139
Coal gas made from wood.... 306
——Batteries for producing electrical energy from carbon. Lorenz..... 18
——Blowers and Exhausters. Buffalo Forge Co.... *383
——Cleaning. Hardie. (A.).... 425
——Engines, use of. Langton.... 106
——Engines. Crossley. Power and Mining Machinery.. .... *515
——Law, constant in. Berthelot. Nernst. (S.).. 428
Lighter, electric. Rothstein. (A.).... 327
Power. Power plant of Montezuma Copper Co. Langton.... *104
——Producers. Loomis-Pettebone.... 105
Suction. Nagel *433
Power and mining machinery.... *515
Producer, gas versus waterpower. Nagel.. 145
General Electric Co. Dynamos for electrolytic work.. .... *77
Exhibit.... *379
Generators. See Dynamos.
German Bunsen Society. Meeting report. Dannecl.....256, 315, 360
Address of Goldschmidt in St. Louis. 413
Germanium.. 13
Germany Chemical Industries.....300, 431
Gibbs, J. W. (S.).... 92
as Helmholtz equation.... 97
——and Daniell cell. Carhart.... 130
Glass "Appert".... 165
——Depositing metals upon. Keppler. (A.) 34
——Formation of glasses. Tammann.... 360
——Resistivity against chemical action. Haber and Schwenke. (S.)..... 159
——See also furnace, Electric, Glass.
Glocken Process. See Sodium Chloride, Electrolysis, Gravity Process.
Glucose from wood. Buchner. (D..... 124
GOLD:
——Bromide of potassium added to cyanide. Cassel. (M.).... 429
——Cathode reduction.. 46
Chlorination plant. Thomson and Goodale. (S.).. 462
——Combined electrolytic and zinc precipitation. Butters.. 207
——Cyanide plant and practice at the Ymir mill. Holden 101
——Development of metallurgy. Butters. 53
——Electrochlorination. Kreuzwalt...*24, 290
——Electrolytic analysis. Perkin and Prebble. (S.).. 159
——Electrolytic extraction. Jory. (A.).... 284
—— Feldkamp. (A.).. .... *112
——Electrolytic extraction from ores and tailings. Fahrig. (A.).... 204
——Electrolytic precipitation.. 126
—— Butters.....55, 204
Hamilton.... 131
—— Christy. (A.).. 205
Apparatus. Jory. (A.).... 238
—— Lead peroxide anodes. Hamilton.. 372
——Electrometallurgy in South Africa. 1897 to 1899.... 53
——Electrolytic Refining. Wohlwill. (S.).....26, 213, 221, 261
——Estimating in working cyanide solutions. (S.). 31
——Filter for extracting from low-grade ores or slimes. Danckwardt. (M.).... 290
Filter presses for cyanide process. Ankeny. (M.) *328
——Filter presses in Australia. Pritchard. (S.).... 248
——from sands. Dixon and Torrente.... 215
——from slimes. Dixon and Torrente..... 216
——Greenawalt electrochlorination process. Perkin 24, 290
——Hendryx agitator and electrolytic precipitation process *286
——Influence of temperature on cyanide process.. 58
——Limitations of cyanide process. Durant.... 107
Metallurgy. By-products. Dixon and Torrente.... 219
——Metallurgy on Rand gold fields. Dixon and Torrente.....*211, 215
——Precipitation from cyanide by zinc or electrolysis. Both electrochemical processes.. 45
——Precipitation from cyanide by zinc-lead couple. Betty, Carter.... 60
——Precipitation from cyanides by zinc-copper couple. Ehrmann..... 54
——Precipitation by zinc and electrolysis. Dixon and Torrente..... 217
——Precipitation plant. Dixon and Torrente.. 218
Refining.... 213
—— Wohlwill.. .... *221, 261
——Rotary apparatus for treating ores by cyanide process. (M.) 328
——and silver sulphide ores. Smelting and electrolysis. Burton. (D.)..... 518
Slimes process of Moore. (M.)..... 328
——Solubility.... 289
——Solubility in oxidizing agents. Lenher Reed.. 422
——Treatment with lime. Anderson. (M.) 235
Buttons. Measurement in blow-pipe analysis. Richards.. .... *208
——Copper, etc., mining by cyanide process. Porter. (M.).... 235
——from pyritic ores or residues. Stark. (M.).... 429
——from telluride ores 42
—— and silver from lead. Parkes process. 220

—and silver from anode slimes in copper refinery. Balbach Co. *306
—and silver. Sulphide ores. Smelting and electrolysis. Burton. (D.)... 548
—Tank for slime treatment. Webb. (M.) *168
—Treating sulphurets. Currie. (M.).. 429
—Treatment of slimes by cyaniding and precipitation on mercury cathode. (S.)... 26
—Zinc versus electrolytic precipitation. Discussion in South Africa..... 60
—See also Plating and Cyanide.
Goldschmidt Thermit Co.....123, 296
—Exhibit..... 376
—See also Aluminothermics.
Governors for water-wheels. Lombard Governor Co. *162
Graham, C. A. Chemical Pottery Works. Hydrogen sulphide generators..... 43
Graphite. Acheson artificial. For experimental electric furnaces..... 186
—Adaptability of articles. Collins..... *277
—Use in metallurgical research. Johnson.. *345
—Artificial from charcoal. Weekbecker. (S.)... *244
—Graphite-copper antifriction metal. (S.)... 69
Gravity process. See Sodium Chloride. Electrolysis. Gravity Process.

H

HALL'S Plating Works. St. Louis Exposition *294
Halogen elements. Potentials. Mott.... *177
Haloids of sodium, calcium, strontium, magnesium, aluminium, molten. Electrolysis. Ombolt. (D.)..... 424
Harbison-Walker Co. 210, 473
Hard rubber pumps for acids..... *209
Hard and soft states in metals. Beilby.. 282
Heavy fireproof wire. By Easton..... 161
Heat, latent of fusion, at high temperatures. Glaser. (S.)..... *200
Heat of neutralization. Westman..... 181
Heat, specific, at high temperatures. Glaser. (S.)..... *200
Helium 12
Heroult, P. L. T..... 434
Hoist. Electric mining. Lidgerwood Mfg. Co. *209
Hydrocarbons of benzene series. Electrolytic oxidation. Perkin..... 487
Hydroelectric plants. (See Water-power.)
Hydrogen. Electrolytic production. Hazard-Flamand. (S.)..... *319
—Oerlikon Co. *293
—Richards 64
—Hutton and Petavel..... *139
Hydrogen sulphide generators..... 43
Hydroxides. Electrolytic production. Hunt 160
Hydroxides and oxides of metals formed by electrolysis. Hunt. (A.)..... 112
Hylotrophy. Ostwald..... 361
Hypochlorite. Formation of. Sadtler.... 96
Hypochlorites. (See also Bleaching.)

I

IMAGES. Metallic by electrolysis. Darling 170
Incandescent gas mantle..... 62
Index. Card index for electrochemistry. Voege 187, 315
Indicators. Concentration of hydrogen ions. Salm. (S.)..... 245
—Sensitiveness of. Salessky and Fels. (S.) 202
—Mixed. Scholtz. (S.)..... 371
Indigo, Brominated. Schmidt and Mueller. (A.)..... 364
Indium 13
Insulating compounds. Bitumen in. (S.) 4, 62
Insulating materials..... 165
Insulation for wires. (S.)..... 248
International Acheson Graphite Co..... 333
—Exhibit *294, *374
—Graphite articles. Collins..... *277
—Use of graphite for metallurgical apparatus *345
International Congress. (See Congress.)
Interrupter. Electrolytic. Electric Appliance Co. *252
Interrupter. Schiedel. (A.)..... 366
—Wehnelt type. Houghton. (A.)..... 114
Iodine. By electrolysis. Parker and Robinson. (D.)..... 13
—Potential. Mott..... *177
—ion. Effect on potential of sodium thiosulphate. Thatcher..... *454
Iodoform from acetone by electrolysis. (S.) 200
Ionic concentrations. Very small. Haber, Bodlaender, Abegg, Danneel. (S.) 150, 320
Ions. Combination with solvent. Morgan and Kanolt..... 207
—Complex in solutions. Abegg.....82, 117
—Energy. Parsons..... 182
—Lighting of. Belton..... 28
—Mobility. Sutherland. (S.)..... 202
—and conductivity. Kohlrausch and Grueneisen. (Si) 461
—in liquid ammonia solutions. Franklin and Cady. (S.)..... 289
Iransference in mixed salts. Loomis and Fausti. (S.)..... 438
Iridium 63, 161
—in gold. Wohlwill..... 223
Iron:
—Castings. Free from strain. Fraley. (D.) 474
—Repairs by thermit..... 405
—Coating with copper, etc. Gaillard, Mignon, Rouart. (D.)..... 434
—Concentrates briquetting. Rouse. (M.) 235
—Dechromizing. Massenez. (M.)..... 469
—Determining sulphur in. Ford and Willey. (S.)..... 462
—Dry-air blast. Gayley. (S.)..... 503
—Electrolytic pure. Burgess and Hambuechen *183
Skrabal. (S.)..... 459
—Gee. Neuburger. (S.)..... 319
—Electrometallurgy. See Furnace, Electric, Iron and Steel.
—Hard-soldering cast iron. Hiller. (M.) 367
—as impurity in voltameter solutions and in copper refining. (S.)..... 68
—Oxide. Dissolving action of ferric sulphate. Thompson..... 228
—Passive state..... 11
—Pig from briquettes. Louis. (S.)..... 462
—Preventing from rusting by sherardizing. (S.)..... 322
—West African smelting house. Bellamy. (S.)..... 502
—Refined by electric current passed through molten metal. Wall. (D.). 434
—Separation from manganese. Koester. (S.) 29
—and steel alloys. Hadfield. (S.)..... 69
—or steel direct from ores. Brown and Reynolds. (M.)..... 235
—and steel. Eldred process for annealing and for rolling mills..... 498
—Iron and Steel Institute. Meeting report 502
—Welding flux. Hout. (M.)..... 235

J

JOHNS-MANVILLE CO.....123, 165
Juices. Purification for making sugar. (A.) 73
—Purified by electrolysis. Kollrepp and Wohl. (A.)..... 113

K

KAHLENBERG, Louis. Portrait..... 190
Kiln. Electric. Dickinson. (A.)..... 504
Kryptol. Resistance material for electric furnaces. Voelker. (A.).....333, 463
Krypton 12

L

LABORATORY course in industrial chemistry. Walker..... 478
—Electrochemical in London and Aachen. (S.)..... 29
—Electrochemical equipment. University of Wisconsin. Burgess..... *189
—Electrochemical. Massachusetts Institute of Technology. Goodwin..... *264
—Karlsruhe. (S.)..... 202
—Utrecht. Cohen. (S.)..... 371
Laboratory and School Supply Co.....123, 165
Exhibit 388
—Krypton 337
Laces. Coating with metals. Keppler. (A.) 34
Lagonda Mfg. Co. Exhibit..... 383
Language. Universal. Ostwald..... 299
Lanyon Zinc Co. Exhibit..... *375
Latent heat of fusion at hight temperatures. Glaser. (S.)..... *200
Lava, uses of..... 516
Lavino, E. J. & Co. Ferro-silicon..... 122
Leaching. Apparatus with automatic movement of ore. Stead. (M.)... 235
Rotary apparatus. Smith. (M.)..... 328
Tank. Webb. (M.)..... 168
—Tanks. Valve. Stewart. (M.)..... 431
Lead:
—Blast furnace. Use of waste gases. Herman. (M.)..... 468
—Carbonate. Basic. See White Lead.
—Chloride. Electrolysis of molten. Lyte. (D.).....517, 518
—From complex sulphides. Burleigh..318, 355
—in Idaho. (S.)..... 160
—Manufacture of spongy. Mercader. (M.) 367
—Metallurgy. Ingalls. (S.)..... 462
—From molten chlorides. Lorenz. (D.) 518
—From molten electrolytes. Guillaume. (D.) 518
—Peroxide. Electrolytic formation from metallic lead. Peters. (S.)..... 159
Lemaout, Backmann (D.)..... 80
—Electrolytic formation. Rokotnitz. (S.) 29
—Electrolytic production. Diamant. (A.) 505
From lead sulphate and bleaching powder. Wohlwill..... 340
Peroxide. (S.)..... 372
Preparation of pure lead Carbonate 187
—Oettli. (A.)..... 463
—Refining. Betts process..... 503
—and tin alloys. Sackur..... 315
Peroxide. (S.)..... 504
—and silver and chlorine from molten electrolyte. Lyte. (D.)..... 518
—Voltameter. Betts and Kern..... 403
—and zinc from complex sulphides. Beadle. (S.)..... 155
—and zinc from molten electrolyte. Lorenz. (D.)..... 518
Leeds & Northrup Co..... 253
—Exhibit 377
Legislation to promote chemical industries. Schweitzer..... 448
Lehigh University.....198, 518
Letter press printing by electrolysis. Darling 170
Le Valley Vitæ Carbon Brush Co..... 208
Lidgerwood Mfg. Co..... 433
—Electric mining hoist..... *209
Exhibit *382
Lighting gas by electricity. Rothstein. (A.) 328
Lignite and peat for fuel. Wotherspoon. (S.) 249
Lime burning. Eldred process..... 497
Limits of physical science. Noyes..... 498
Lithium 12
—from lithium chloride in alcohol. Patten and Mott. (S.)..... 201
Lombard governor for waterwheel governors *162
Loomis-Pettibone gas producers..... *105
—See also Power & Mining Machinery Co.
Luminescence phenomena. Trautz 362
Lunkenheimer Co. 123
—Exhibit *383

M

MANGANESE. In Caucasus..... 106
—Separation from iron. Koester. (S.). 29
Magnesite. Production of..... 473
—Bricks as refractory material. Scott, FitzGerald 454
Magnetic concentrates. Briquetting. Louis. (S.)..... 462
Magnetic concentration. King. (A.)..... 327
—Louis. (S.)..... 286
—Zinc ores. Payne. (S.)..... 286
—Wetherell. (S.)..... 427
Magnesium peroxide. Electrolytic production. Hinz. (A.)..... 239
Mallinckrodt Chem. Wks. exhibit..... 376
Manganese. Analysis. Koester..... 371
—free from carbon. Goldschmidt..... 146
—By electrolysis. Richards. (S.)..... 199
—and copper alloys.....146, 247
—and tin alloys..... 147
—and zinc alloys..... 147
Mannite from glucose. Hough. (D.)..... 50
Manure from apatite. Palmaer..... 470
Mass action and toxines. Arrhenius..... 363
Massachusetts Institute of Technology. Electrochemical laboratory. Goodwin. *264
Matter and electricity. Lodge..... 315
Measurements in electrochemical laboratory. Burgess..... *193
Measuring conductivity of copper electrolytes. Addicks..... *306
Medicine and freezing point determinations. Schroeder..... 362
Melting point. Determination. Day and Allen *500
—Graphite apparatus for determining.. *346
—Iron-carbon alloys. Carpenter and Keeling. (S.)..... 289
Merck & Co..... 210
Mercuric cyanide. Effect on oxidation potential of sodium thiosulphate. Thatcher *453
Mercurous sulphate. Electrolytic production. Carhart and Hulett.....*176, *407
—Electrolytic production. Wolff..... 175
—Preparation of. Smith. (S.)..... 427
Mercury. In California. Forstner. (S.).. 462
—Cathode for gold precipitation. (S.). 26
—Cathode cell. See Sodium chloride. Electrolysis. Mercury Cathode.
—Electrodes. Construction. Winsmore. (S.) *427
—Still. Condenser for extraction. (M.) 469
—Trough for electrode connections..... 57
Metachlorbenzaldehyde 341
Meta-dinitrobenzene reduced to meta-phenylendiamin. Buchner. (D.).. 124
Meta-phenylendiamin from meta-dinitrobenzene. Buchner. (D.)..... 124
Metals:
—Production of U. S. in 1903..... 68
—Statistics 4
—Metallic images by electrolysis. Darling 170

—Metallic structure. Evolution. Carfand. (S.) 463
Electrochemical series. Kahlenberg.. *402
Pure, tree from carbon. Gold-schmidt. 145
Kueegelgn and Stewart. (M.).. 468
—Hard and soft states. Beilby..... 282
—in sea-water. Diegel. (S.)..... 321
—Reduced from oxides. Kuegelgen and Dameel. (S.)..... *465
Metallography 47
Metallurgical Co. of America..... 296
Metallurgy. Applications of electricity. Richards. (S.).. 198
Meteorit 123
Meters. Electrolytic 416
Methyl chloride..... 143
Methylene chloride. Production. Winteler 341
Metric system in Mexico and Cuba..... 136
Michigan Alkali Co. (S.)..... 115
Microstructure of metals and alloys..... 46
—by Campbell..... *49
Milk. Sterilization. (S.)..... 459
Mineral chemistry. Relation to other sciences. Moissan 138
Mineral production of U. S. in 1903..... 68
Mining Magazine 329
Mining in U. S..... 463
Missouri Electric Water Purifying Co. exhibit 378
Mobility. Ionic. Sutherland. (S.)..... 292
and conductivity. Kohlrausch and Grunenisen. (S.)..... 461
Moctezuma Copper Co. power plant. Langton *104
Molecular attraction. Mills. (S.)..... 370
Molecular conductivity. Reed..... 179
Molecular weights. Ramsay..... 438
Molding case for electrotyping. Welsh. (A.) 114
Molten electrolytes. Cell for. Rennerfelt. Case. (D.)..... 474
—Graban. (D.)..... 474
—Rogers. (D.)..... 474
Molybdenum 63, 147
—in tungsten steels. (S.)..... 321
—Determined in steel. Cruser and Miller. (S.)..... 462
Monochloracetic acid. Production. Winteler 341
Monochlor benzene..... 341
Morse Chain Co. Silent chain drive..... *515

N

N-RAYS. Chemical applications. (S.)... 290
Nascent state. Reed. 422
National Carbon Co. Exhibit..... 383
National Electric Co. Exhibit..... *381
National Electrolytic Co..... 517
Neon 12
Nernst-Thomson rule. Schlundt. (S.).... 158
Neutralization heat. Westman..... 181
Niagrite. Johns-Manville Co..... 79
Nichols, Wm. H. Biography and portrait *347

NICKEL:
—Electrolytic production. Hess. (S.).. 499
—Apparatus for electrolytic analysis. Browne *14
—Electrolytic removing from iron..... 11
—in Norway. (S.)..... 372
Plating. (S.)..... 28
Beadle. (S.)..... 159
on sheet zinc. Brandely. (S.)..... 499
Reduction of smelting furnace. Maffett. (M.)..... 508
Refining. Guenther. (S.)..... 156
—Carbonyl. Mond, Dewar. (M.)..... 291
—Nitrate. Thermo e. m. f. Meyer. (S.) 428
—Nickel-steel. Effect of sea-water. Diegel. (S.)..... 321
—Nickel-tungsten alloy 147
Niles-Bement-Pond Co. Exhibit..... 383
Niles Tool Works. Filter presses..... 163
Niter cake converted into neutral salts. Darling. (D.)..... 44
Nitrates of potassium or sodium. Electrolysis of molten. (D.)..... 14
Nitrobenzene reduced to anilin chloride. Buchner. (D.) 124
Nitrobenzene reduced to anilin. Buchner. (D.) 124
(A.) 288
Nitro compounds. Reduction. Buchner. (A.) 284
—Reduced to amines. Buchner. (D.).. 124
Nitrogen. Manufacture and applications. Hutton and Petavel *139
Nitrogen. Fixation of atmospheric. (S.), 28, 288
—Kowalski and Moscicki. (A.)..... *152
Lepol. (S.) 199
—Atmospheric Products Co..... 250
Birkeland. (A.) 307
—Birkeland and Eyde process. Edsirom *399
Kassel. (S.) 504
Nodium 95
Normal electrode. (See Standard Electrode.)
Northern Elec. Mfg. Co. Exhibit..... *381
Nutation. Electrochemical 251

O

OERLIKON CO. Electrolytic production of hydrogen and oxygen..... *233
Oil. Extraction of essential oil. Burton. A. 327
Organic chemistry. Products of U. S. (S.) 203
—Present problems. Noyes 438
Osmium 65
—Iridium from gold. Wohlwill..... 223
Osmotic pressure and alternating current. 187
Osmotic theory of e. m. f's..... 98
Ostwald. Bancroft on 452
Otto Gas Engine Works. Exhibit..... 379
Overvoltage. Anodic. (S.)..... 501
Smith 97
Oxidation of iodates. Mueller. (S.)..... 114
Oxides and hydroxides of metals formed by electrolysis. Hunt. (A.)....112, 160
Oxidizing agents. Potentials of. Scobai. (S.) 28
Oxidation. Electrolytic. See also the different substances.
Oxygen. Anodic development. Foerster and Pignet *459
—Electrolytic production. Oerlikon Co. *293
— Richards 64
— Hazard-Flamand. (S.)..... *319
Oxygen-lift cell. See Storage Battery. Edison nickel-iron.
Ozone. Determination in gases. Bonsfield. (S.) 248
OZONE:
—Formation. Clement. (S.)..... 371
—Generation. Gray. (S.)..... *198
—Use for water sterilization. Erlwein. (S.) *65
—Generator. Blackmarr and Willford. (A.) 73, 74
— Elworthy. (S.) 199
— Kershaw. (S.) *426
— Marmier & Abraham..... *426
— Miller and Ashley. (A.)..... 73
— Otto. (A.) 74, *426
— Vosmaer. (A.) 163, *511
— United Water Improvement Co... 511

P

PALLADIUM 63
—from electrolytic refineries..... 224
—Wharton 234
Pan furnace for treating byproducts of cyanide works. Dixon and Torrente 219
Para-amido-phenol-sulphonic acid by electrolysis. Noyes and Clement. (D.) 44
Paradichloraniline 341
Paradichlorbenzene 341
Paranitrotoluene reduced to paratodin. Buchner. (D.) 124
Paraphenylenediamine from para-amidoazo-benzol. Buchner. (D.) 210
Paratoluidin from paranitrotoluen. Buchner. (D.) 124
Passivity of metals. Mueller..... 277
—Sackur. (S.) 501
Patent laws and chemical industries. Schweitzer 448
Peat and lignite for fuel. Wotherspoon. (S.) 249
Peat. Removing water from. Kitler. (A.) 507
Percarbonates by electrolysis. Constam and Hansen. (D.) 44
Periodates. Formation. Mueller. (S.).. 114
—Influence of inert ions upon formation. Mueller. (S.) 501
Periodic system of elements, explained by electronic structure of atoms. Thomson. (S.) 156
Persulphates. Effect of fluorine ions on formation. Mueller. (S.) 501
Perth Amboy Chemical Works..... 333
Phase rule and hylotropy. Ostwald..... 361
Phenylnitromethane reduced to benzylamin. Buchner. (D.) 124
Phosgene 143
Phosphates. Fertilizers by electrolysis. Palmaer 470
—of alkalies by electrolysis. Albert. (D.) 44
—Electrolytic treatment. Cheesman. (D.) 124
Phosphorus. Abuses of. (S.)..... 372
—Chlorides from electrolytic chlorine. Winteler *340
—Removed from ores. Eames. (D.).. 474
Photography. Color 293
Color by electrolysis. (S.) 69
Physical chemistry. Development. van't Hoff 438
Physico-Chemical Review. (S.)..... 21
Pioneers of electrochemistry. T. A. Edison *103
Piperidin from pyridin. Pip. (D.)..... 80
Pitkin & Co., James. Pyrometer..... 510
PLATING:
Apparatus. King. (A.) 466
—Chemistry of electroplating. Bancroft 389, 400
—Effect of stirring. Sand. (S.)..... 320
Enamelined vessels. Manning. (A.) 71
—Establishments. Pfanhauser. (S.)... 370
—Glass, laces, fabrics with metals. Keppler. (A.) 31
Machine. Bailey. (A.)..... 466
—Organic matter in plating solutions. (S.) 28
—Sheet zinc with nickel. Brandely. (S.) 499
—Sheet zinc with nickel or copper. (S.) 248
—Sound records. Gurney. (A.)..... 242
—upon aluminium. Burgess and Hambuechen 85
—Use of caustic potash..... 121
—in vacuo. Edison. (A.)..... *364
—with brass. Davis. (S.)..... 209
—with nickel. (S.) 459
with silver. Cyanide versus chloride bath. (S.) 209
—See also the different metals.
PLATINUM:
—General 210, 473
—Electrolytic solution in hydrochloric acid. Tommasi. (S.)..... 461
—in gold. Wohlwill 222
—Recovered from gold 213
—Structure, occlusion of gases, deterioration. Campbell *259
Platinum metals 63
Porous diaphragm. Perkin 281
(S.) *370
Sadtler 187
Potash. German syndicate..... 128
Potassium acetate. Electrolysis. Foerster and Piguet. (S.)..... 459
Potassium carbonate and chlorine from molten electrolyte. Hyte. (D.).. 474
Potassium chloride. Electrolysis. Winteler 391
—See also Sodium Chloride. Electrolysis.
Potassium-magnesium carbonate. Auerbach. (S.) 160
Potassium and potassium cyanide made in electric furnace. Dankwardt. (A.) 70
Potassium and aluminium double chloride. Purification by electrolysis. Castner. (D.) 434
Potential. Measurement in stationary liquids. Sand 486
—of oxidizing agents. Scobai. (S.)..... 28
—Single of halozen elements. Mott.... *177
of electrodes. Oettingen 58
Potentiometer. Burgess 194
Power. Cost of development of water power. Bell 301
—Cost for reduction works. Simpson. 421
—Fuel tests for economy. Kershaw. (S.) 248
—Producer gas versus water power. Nagel 145
—Suction gas producer. Nagel..... *432
—Transmission for electrochemical works. Bell 301
—Utilization of peat and lignite. (S.).. 249
—Water, steam, gas..... 127
—Power & Mining Machinery Co..79, 165, 516
Plant of *513
Precious metals. See Gold.
PRIMARY BATTERY:
—Copper-lead. Calculation of e. m. f. Lorenz 16
—Exciting compound. (A.) 113
—Jacques. Theory by Haber and Bruner 401
Primary cell. "Nitron" depolarizer. (S.) 203
—Producing electric energy from an endothermic reaction. Lorenz.. 16
—Regeneration. Hess. (D.)..... 80
— Gardiner 44
—Structure of zinc electrodes. Job. (S.) *119
—Zinc-silver chloride. Thermochemical calculation of e. m. f. Lorenz. 16
—Inventors:
— Atwood. Exciting liquid. (A.).. 286
— Bousfield. Double fluid, acid-hydroxide. (S.) 203, 170
— Dodge electrode lamp for. (A.).. 506
— Edison. Electrodes for. (A.).... 366
— Gladstone. Support of electrodes. (A.) 72
— Halsey. Movable electrode. (A.) 72
— Haschke. (A.) 186
— Heym. Pocket. (A.) 113
— Hubbell. For portable lamp. (A.) 153
— Hutchinson. Sealing. (A.)..... 72
— Jackson. Holder for. (A.)..... 506
— Jacobson. (A.) 425
— Jacques. Theory by Haber and Bruner. (S.) 428
— Jone. gas. (A.) 326
— Jone. By Reed 18
— Kamperdyk. (A.), 324, (A.) 327, (A.) 423
Lord. (A.) 286
Mackey. (A.) 506
— Marschall. Lerlanche type..... 63
— Noble and Anderson. (A.)..... 242
— Pedrazzi. (A.) 72
— Poerske and Wedekind. Electrodes for alkaline solutions. (A.) 286
Pullen 506
— Reid. (A.) *242
— Reid. By Reed 18
— Roberts. (A.) 506
— Schoenmehl. Zinc-copper oxide. (A.) 207

—— Schoenmehl. (A.) 326
—— Strickland. (A.) 72
—— Tweedy. Construction of double-fluid cell. (A.) 72
—— Whitman. Containing vessel. (A.) 207
—— Winters. Construction. (A.) 112
—— Yai. (A.) 72
—— See also Dry Battery.
Primos Chemical Co. Exhibit 388
Printing. Thin-film electrolysis. Darling. 170
Producer, gas. Power & Mining Co. *513
Producer gas versus water power. Nagel. 145
Purification. Beet juices for making sugar. (A.) 73
——Fats by electrolysis. Sohwahn. (D.) 43
——of juices by electrolysis. Kollrepp and Wohl. (A.) 113
——Liquids. Kartzmark. (A.) 114
——Water by electrolysis. Boucher. (A.) 243
—— George. (A.) 286
—— Watson. (A.) 286
—— Jewell and McGee. (A.) 366
—— Zerbe. (A.) 366
—— Kune. (A.) 468
—— Laugley 417
—— See also Ozone.
——of water with sulphate of iron 43
Purifier and filter for feed water. Dougherty. (A.) *467
Pyrometer. Electric. (S.) *32
——Le Chatelier *471
——for metallurgical work. (S.).290, 431,*471, 510
——Platinum resistance. Campbell 259
——Thermo-electric of platinum. Campbell 260
——Waidner 510

Q

QUARTZ. Fused quartz thermometers. Siebert. (S.) 159
——Manufacture or repair of quartz articles. Askenasy. (S.) 463
——Tubes. Manufacture. Thomson. (M.) 280
Quicksilver in California. Forstner. (S.) 462

R

RADIOACTIVE atom. Reuterdahl 250
Radioactive elements 11
Radio-activity. Theory. Cabot 160
——Curie. (S.) 68
Radium 12, 198
——from American ores. Phillips. (S.)... 247
Ramsay, Sir William. Portrait *418
Rare earths 61
Rare elements. Lenher 61
Records plating. Edison. (A.) *364
Rectifier. Electrolytic. Bancroft 413
——Chuter *76
——Cook. (S.) 117
——Nodon 416
——Scheidel. (A.) 366
——Suitable electrolytes. Mott 444
Reducing agent. Titanous sodium sulphate. Spence. (A.) 239

REDUCTION:
——of azo-compounds. Buchner. (D.).... 210
——Electrochemical. Elbs 361
——of metals. Nagel 302
——Influence of cathodic meterial upon. Loeb and Schmitt. (S.) 501
——Temperature of zinc oxide. Johnson. 185
——of threevalent vanadium salts. Buelteman. (S.) 156
——See also the different substances.
Refining tanks. Construction. Schwarz. (A.) 70
Refining. See the different metals.
Refractory materials. For electric resistance furnaces. Fitzgerald 439
——for furnace linings 435
——Artificial graphite 186
——Magnesite 510
——Magnesite bricks. Scott. FitzGerald 454
Regenerative steam accumulators. Deminge. (S.) 502
Renney & Son, Richard C. 210
——Acid-resisting bricks *42
Repairs of castings. Thermit process. See Aluminothermics.
Resistance. Specific of solutions measurement. Burgess *195
——near critical point. Kraus. (S.)..... 201
——at high temperatures. Noyes and Coolidge. (S.) 201
Resistance of electrolytes measured. Burgess *195
Resistors 490
Rheostats for electrochemical laboratories 192, 196
Richards, J. W. Portrait 178
Roaster. Combination with ozonizer. Thompson. (D.) 434
Roasting dish of graphite *346
Roberts Chemical Co. Caustic potash.... 121
Roessler & Hasslacher Chem. Co. Exhibit 331, 376
Roll. Composite metal. Reed. (A.)..... 36
Rotating cathode. Medway. (S.)..... 427
Rubber. Acid-proof 48
Rubidium 12
Rubies. Artificial 460
Rutile 296

S

ST. LAWRENCE River Power Co.....296, 516
St. Louis Exposition 516
——International Acheson Graphite Co... *294
——Hall's Plating Works *294
——Baker & Co. *331
——Chemical Exhibit German Gov't..... 331
——Roessler & Hasslacher Chem. Co..... 331
——International Acheson Graphite Co... *374
——Carborundum Co. *374
——Electric Storage Battery Co. 375
——Edison Storage Battery Co. 375
——Lanyon Zinc Co. *375
——Goldschmidt Thermit Co. 376
——Roessler & Hasslacher Chem. Co..... 376
——Mallinckrodt Chemical Works..... 376
——Solvay Process Co. *377
——American Hard Rubber Co. *377
——Allis-Chalmers Co. 377
——Leeds & Northup Co. *377
——Missouri Elec. Water Purif. Co..... 378
——Buffalo Forge Co. 378
——R. D. Wood & Co. 378
——Otto Gas Engine Works 379
——Stilwell-Bierce & Smith-Vaile Co..... 379
——General Electric Co. *379
——Walker Manufacturing Co. *380
——Crocker-Wheeler Co. *380
——Northern Elec. Mfg. Co. *381
——National Electric Co. *381
——Electric Controller & Supply Co..... 382
——Lidgerwood Mfg. Co. *382
——Lunkenheimer Co. *383
——Niles-Bement-Pond Co. 383
——Prime Chemical Co. 383
——C. O. Bartlett & Snow Co. 383
——Bausch & Loueb Optical Co. 383
——Eimer & Amend 383
——Zucker & Levett & Loeb Co. 383
——Lagonda Mfg. Co. 383
——Weston Elec. Inst. Co. 383
——National Carbon Co. 383
——Laboratory & School Supply Co..... 383
——Ward-Leonard Elec. Co. 383
——Willard Storage Battery Co. 383
——Denver Fire Clay Co. 383
Salts. Fused. Electrolysis. Lorenz..... *412
Saponification of fatty substances. Magnier. (D.) 80
Sargent & Co., E. H. 516
Schutte & Koerting Co. Sulphur furnace *253
——Lead-lined valve *472
Science. Limits of physical. Noyes..... 498
Scientific Materials Co. 253
——Appert glass 165
Sea-water. Effect on metals. Diegel. (S.) 321
Seger cones. Graphite rack and box for.. *346
Selenium 62
Semi-permeable diaphragm. Sebor. (S.). 389
Separating solids from liquids. Centrifugal machine *43
Separation, Electrolytic. See the different metals.
Separation, electromagnetic and electrostatic. (S.) 115
Separator. Magnetic. (See Magnetic Concentration.)
Series. Electrochemical of metals. Kahlenberg *402
Sewage treatment by electrolysis. Schweitzer. (A.) *327
Sherardizing 322
Silent chain drive. Morse Chain Co..... *515
Silica tubes. Manufacture. Thomson. (M.) *290
Silicates. Table of 360
Silicon made in electric furnace 7
——Tone (A.) 111
Silico-carbides as refractory material..... 439
——Analysis 443
Silicon and carbon chlorides made in electric furnace. Machalske. (A.)..... 33
Silicon-copper in brass foundries 121
Siloxicon made in electric furnace 7
Silver. See also Gold.
——Buttons. Measurement in blow-pipe analysis. Richards *298
——Cleaning 75
——Electrochemical equivalent. von Dijk and Kunst. (S.) 117
—— Electrochemical equivalent.....406, 407
——Electrolytic precipitation. Hamilton. 131
——Extraction and precipitation. See also Gold.
——Greenawalt electrochlorination process. By Perkins *24
——Microstructure of electrolytic..... *50
——from molten electrolytes. Guillaume. (D.) 518
——Refining. (S.) 319
——and lead and chlorine from molten electrolyte. Lyte. (D.) 518
—— Legal specifications 406
—— Guthe. (S.) 427
——and gold from anode slimes of copper refining. Balbach Co. *306
Slags. Mathesius 360
Slotting by electrolysis. Cowper-Coles. (S.) 28
Society of Chemical Industry. New York meeting 148, 300, 338
Banquet 388
——Report of New York meeting.....417, 388

SODIUM:
——from molten electrolytes. Rogers, Castner, Grabau. (D.) 296
—— Grabau, Darling, Vantin, Hulin, Borchers, Boelsterli, Darling, Danckwardt 334
—— Becker process. By Carrier..... *357
——from fused sodium hydroxide. Ewan. (A.) 34
Ewan. (A.) 70
——Salts. Molten. Electrolysis. Acker, Scholl. (D.) 434
——Sodium chloride. Molten electrolysis. Blackmore. (A.) *239
Hulin. (D.) 518
—— Kuegelgen and Danneel. (S.)..... *465
Stockem (S.) 156
——Sodium chloride solution in water. Electrolysis. Mercury cathode. Brichaux. (A.) *505
—— Blackmore. (A.) 239
—— Gurwitsch-Kettenbeil and Carrier. (S.) 369
Hannon. (A.) *373
Rink. (A.) *111
—— Roepper and Harmon. (A.)..... *465
—— Truesdell 119
——Diaphragm cells. Characteristics of diaphragm. Tardy and Guye. (S.) 288
—— Calculation. Guye. (S.) 66
——Gravity process. Steiner. (S.)..... *243
——Sodium chloride electrolysis compared with potassium chloride. Winteler 391
—— Anode construction. Blackman. (A.) 285
—— Iron oxide anodes for. Blackman. (A.) 70
—— Extracting gold and silver..... *24
—— See also Bleaching.
Sodium salts. Electrolysis of. Acker, Becker, Cowles. (D.) 384
——Carbonate and chlorine from molten electrolyte. Hyte. (D.) 474
——Nitrite and zinc oxide. Kendall. (D.) 80
Sodium and aluminium double chloride. Purification by electrolysis. Castner (D.) 434
——and sodium cyanide made in electric furnace. Dankwardt. (A.)..... 70
Soft and hard states in metals. Beilby.. 282
Solutions. Non-aqueous. Dutoit. (S.).. 201
——Theory of Traube. (S.) 371
Solvay Process Co. Exhibit *377
Solvent . Combination with ions. Morgan and Kanolt 207
Spark discharges. See Discharges.
Specific heat at high temperatures. Glaser. (S.) *200
Spectra of elements. Runge. (S.)..... 160
Spectroscopic methods. Bolton. (S.)..... 29
Spelter 252
——Containing cadmium. (S.) 462
Spongy copper deposit. Thompson..... *230
Standard cells. Wolff 141
Construction. Carhart and Hulett *176, 440
——Mercurous sulphate. Smith. (S.)... 427
——Construction. Winsmore. (S.)..... *427
——Daniell cell. Rosa. (S.) 246
Standard electrode. Construction. Danneel. (S.) 427
Starch. Electrolytic process. (S.)..... 427
Statistics of metals 4
STEEL:
——Alloy for deoxidizing. G. G. Blackwell Sons & Co. 295
——Application of phase rule to iron-carbon alloys. Roozeboom..... 276
——Castings. Prevention of pipes and blowholes. Meslans. (M.)..... 367
Continuous steel process. (S.) 215
——Determination of carbon and phosphorus. Iron and Steel Inst. (S.).. 503
——Determining molybdenum in. Cruser and Miller. (S.) 462
——Diagram of alloys of iron and carbon. *49
——Direct from ores. Brown and Reynolds (M.) 235
——Effect of sea water on nickel steel. Diegel. (S.) 321
——Electrometallurgy. (See Furnace, Electric, Iron and Steel.
——Hardening. Heyn 276
——High-speed tool, tungsten and molybdenum in. (S.) 321
—— (S.) 321
——Influence of carbon, phosphorus, manganese and sulphur on strength of open-hearth steel. Campbell. (S.) 503
Melting points of pure iron alloys. Carpenter and Keeling. (S.)..... 289
——Microstructure of *51
——Nickel-ferrovanadium. Manby. (M.). 468
——Plant in Canada 470
Preventing pipes and blowholes by antipiping thermit 405
——Preventing from rusting by sherardizing. (S.) 322
——Recarburizing scrap steel. Atha. (M.) 367, 508
Repairs by thermit 175
——Special. Metcalf. (S.) 429
—— Nickel, manganese, tungsten. Tressider. (M.) 507

—Thermomagnetic selector. Sauveur and Whiting (S.) 245
Titaniferous ore in basic open hearth. Carlsson. (M.) 430
—Tungsten steel. Guillet. (S.)..... 321
—for armor-plates, tools, etc. Direct casting and hardening. Everette. (M.).. 508
—Use of ferro-titanium. Goldschmidt. Iron cast-iron by electrolysis in molten state. Hiama (D.)..... 434
—from iron continuously. Kern. (M.) 508
—from pig-iron by electrolysis in molten state. Nes. (D.)..... 434
—from pulverized ores, mad into briquettes. Alzugaray. (M.) 430
—Refined by electric current pressed through molten metal. Wall. (D.) 434
Sterilizing liquids.. (See also Purifying.
Sterilizing Milk. Guignard. (S.)..... 459
Sterilizing water. Wessels. (A.)..... 114
—Wessels. (A.).. 114
—by ozone. Erlwein. (S.)..... *65
—See also Purifying and Water.
Structure. Evolution of metallic. Cartrand. (S.)..... 463
Stilwell-Bierce and Smith-Vaile Co. Exhibit.. 379
Stimulation. Electric. Nernst..... 363
Stirring and leaching apparatus. Stead. (M.).. 235
—during electrolysis. Sand. (S.)..... 329
STORAGE BATTERY:
—Apple. (A.)..... 211, 365, 467
—Askew. Electrode. (A.)..... 113
—Betts. Lead fluosilicate electrolyte. (A.).. ..... *241
—Beckmann. Peroxide formation. (D.) 80
Bijur. (A.)..... 113, 240
—Bryan. Construction. (A.)..... 113
—Buehne. (A.)..... 113
—Burt. Construction. Artificial coating. (A.).. 152
—Cable, for submarines. (A.)..... 365
Chamberlain. Regulating temperature of. (A.).. 71
—Clare. (A.).. 325
—Colletas. (A.)..... 285
—De Seduefft. (A.)..... 425
—Diamant. Process of preparing positive plate. (A.)..... 505
Dickson. (A.).. 35
—Duntley. (A.).. 326
Edison nickel-iron. 3, *36
— Construction and tests..... *36
— Janet. (S.)..... 68
— Discussion in London. (S.)..... *118
Jouast. (S.) 118
— Construction and tray. (A.)..... 152
— Fliess.. ..... 169, 289
— Theory. Schoop..... *272, *310
— By Kennelly and Whiting..... *409
— Edison versus Jungner..... *317
— Separating entrained globules from gases, (A.)..... *325
— Rendering gases non-explosive. (A.).. ..... *424
— for traction. Stewart. (S.)..... 428
— Lead accumulator and oxygen—lift cell. 297
—Elieson and Bobinsky. (A.)..... 113
—Elieson. (A.).. 206
—Feldkamp. (A.)..... 112
—Fiedler. Zinc-lead. (A.)..... 34, 35, 466
—Flanders. (A.) Electrode supports. 240
Ford. Zinc-copper. (A.)..... 35
—Fortun and Semprun. (A.)..... 242
—Frank. Electrode. (A.)..... 113, 152
—Frost. (A.).. ..... *206
—Hartung. (A.) Construction with tubes.. 71
—Hager. (A.).. 113
—Haschke. (A.).. 186
—Jungner nickel-iron. (F.)..... 118, 159, 289
Theory. *272, *310
— Jungner versus Edison..... *317
—Kennedy. (A.).. 35
—Kitsee. (A.)..... 326, 365
—Lake. Connection of plates. (A.).... 152
—Lough. Apparatus for washing. (A.) 365
Lyons and Broadwell. (A.).... 71, 365
Madon. (A.)..... 325
Meserole. (A.).. 240
—Meygret. Protective sheath for plates. (A.).. 206
—Meygret. Plate. (A.)..... *285
—Morgan. (A.).. 505
—Mueller. Stopper for portable. (A.). 152
—Niblett. (A.)..... 241
—Poerske and Wedekind. Electrodes for alkaline. (A.)..... 286
Poppenberg. (A.) 71, 285
Porter. (A.).. 325
Potter Preventing detachment of lugs. (A.).. 466
Rabbidi. (A.)..... 71, 371
—Redmont. (A.)..... 241
—Reed. (A.).. 241
—Rodman. Wooden separator. (A.).. 72
Schrader. (A.) 285
—Schoenmehl. Copper oxide electrode construction. (A.).. 71
Smith. Plate. (A.)..... *285
—Sperry. (A.).. 506
Walker. (A.) 365
Willard. Envelope for plates. (A.). 285, 326
Woodland McMullen. (A.) *467
—Action of light upon the formation of plates. (S.)..... 117
— Schoop. (S.).. 246
—Calculation of line batteries. Winship.. 214
—Care of. (S.)..... 372
—Electrolytic formation of lead peroxide. See Lead Peroxide.
—Semi-solid electrolyte for. Peto and Cadett. (A.).. 35
—Total and free energy of lead cell. Lehfeldt. 4
—Theoretical capacity. Loppe. (S.).. 202
—Theory of lead accumulators. Bary. (S.).. 428
Auxiliary electrodes for tests. Liagre. (S.).. 428
Concentration changes in lead accumulator and Edison battery..... 255
—High discharge rates. Donaldson. (S.).. 245
Improvements in. (S.)..... 246
Lead poisoning. (S.)..... 372
—Plates made from spongy lead reduced from galena. Salom..... 148
Plates. Strength and porosity..... 148
Silvey system of lighting railway cars. 79
—in central station equipment. Goettling.. 416
—in railway service. Entz..... 417
Traction. (S.)..... 30, 117
Palitzsch. (S.) 206
— Stewart. (S.).. 428
— Telephone practice. (S.)..... 372
Storage of gases. Hutton and Petavel 143
Stripping of metals by electrolysis. Burgess.. ..... *8
Structure and Tension. Nagel..... 97
Sulphide ores. Swinburne-Ashcroft process for treating complex..... 402
—or sulphuretted ores smelting. Danckwardt. (A.)..... 109
Sulphides. Electrolytic winning of zinc and lead from complex sulphides. Burleigh. (S.).. 318
Insoluble by electrolysis. Richards and Roepper. (D.)..... 44
—Smelting of complex. Beadle. (S.).. 155
—Zinc and lead from complex sulphide ores.. 355
Sulphites acid sodium and calcium. Electrolysis. Frank. (S.)..... 320
Electrolysis. Friessner. (S.)..... 245
Sulphur determined in iron. Ford and Walley. (S.).. 462
— —Removal from ores and fumes. (D.).. 474
—Chloride from electrolytic chlorine. Winteler.. ..... *339
—Furnace. Schutte & Koerting Co..... *256
Sulphuric acid by contact process..... 347
—from sulphurous acid gas. Salom. (A.).. ..... *151
—and caustic by electrolysis of molten nitrates. Darling. (D.).. 44
—Production in Kansas..... 160
Transport number. Tower. (S.)..... 461
Sulphurous oxide. Reducing action on ferric sulphate. Thompson..... 228
Stove. Thermit cooking and roasting.... 406
Strontium. Melting point. Stockem. (S.) 156
Sugar from beet juice. Miller. (A.)..... 73

T

TANKS. For electrolytic deposition. Jory. (A.)..... 238
—Apparatus for circulation of liquids. (A.) 239
—for electrolytic stripping process..... *8
—for refining metals. Schwarz. (A.).. 70
Tantalum 62
Tariff and chemical industries. Schweitzer 448
Tellurium 62
Temperature measurements. Reduction of zinc oxide. Johnson..... *185
— up to 1600 degs. C. Day and Allen. (S.) *500
—Testing in electric furnace. Fitz-Gerald 415
Tension and structure. Nagel 97
Testing materials. Berlin bureau. (S.). 372
Thallium 13
Thermochemistry of electrolytic dissociation. Reed 65
Thermit 296
Analysis and tests 165
Anti-pitting. Goldschmidt 405
—See also Aluminothermics.
Thermocouples. Day and Allen. (S.).... *509
Thermodynamical calculation of e. m. f's. 97
Thermo e. m. f. nickel nitrate. Meyer. (S.) 428
Thermomagnetic selector for steel. Sauveur and Whiting (S.) 245
Thermometers from fused quartz for high temperatures. Schott (S.) 159
Timbering in mines..... 463
TIN:
—by electrolysis. Quintaine. (A.)..... 239
—Detinning scrap. (S.)..... 6, 19, 218, 369
— with electrolytic chlorine. Winteler *339
from oxide. Kaegebein and Danneel. (A.) *465
Production. Radtsen (S.) 156
—Reduction of tin oxide in molten sodium chloride. Inglis. (D.)..... 518
—Tetrachloride from tin scrap. Winteler *339
—and lead alloys. Sackur. (S.)..... 315
— Peetz. (S.) 501
Titanium 13
—Titanium alloys, titanium carbide. Moissan. (D.) 518
Trichloride 250
Titanous sodium sulphate. Spencer. (A.) 239
Towers. Glover and Gay Lussac. Acid resisting bricks *42
Toxines and chemical mass action. Arrhenius 363
Transference. Ionic in fused salts. Lorenz and Fausti. (S.) 428
Transport number of sulphuric acid. Tower. (S.) 461
Trichloracetic acid 341
Tube electric furnace. Potter. (A.).... *203
Tungsten 63
—Atomic weight. Smith and Exner. (S.) 247
—Steels. Guillet. (S.) 321
—Le Chatelier. (S.)..... 321

U

UNION ENGINEERING BUILDING, ... 128, 147, 209, 302
United Water Improvement Co. Water sterilization. Vosmaer system *511
Units. Electrical 416
— Proposed International Commission 387
— Wolff 174
University of Wisconsin. Electrochemistry at. Burgess *189
Uranium 62

V

VACUUM, drying apparatus..... *76
Valence and colloidal precipitation..... 446
Valve. Electrolytic. (See Rectifier, Electrolytic.)
—Kurzwernhart. (M.) 291
—for leaching tanks. Stewart. (M.)... 431
—Lead-lined for handling acids. Schulte & Koerting Co..... *472
—Reversing. Hume. (M.) 291
—Hot-blast. Kennedy. (M.)..... 291
Vanadium 62
—and alloys. Manufacture. Gin. (A.) *324
—Threevalent vanadium salts by electrolytic reduction. Bueltsman. (S.) 156
Vanillin by electrolysis. Otto and Verley. (D.) 44
Varnish by electrolysis. Pfanne. (D.).. 44
Viscosity. Fawsitt 249
—Voltage, composite. Richards..... 95, 178
Voltameter. Copper., Adams and MacNutt 183
Lead. Betts and Kern..... —
Silver. Guthe. (S.) 288, 406
— Specifications 406

W

WARD LEONARD, ELEC. CO. Exhibit 383
Water. Electrolysis of. (S.)..... 28
— Richards 61
— Beesen. (S.) 202
—Electrolysis. Hazard-Flamand. (S.).. *319
—Electrolysis with alternating currents. van Name and Graefenberg. (S.) 245
—Purification, with sulphate of iron.... 43
— See also Purifying Liquids.
—Purification by electrolysis..... —
Boucher. (A.) 243
Frazier. (A.) 73
George. (A.) 286
— Kune. (A.) 468
— Langley 417
— Moeller. (A.) 73
— Watson. (A.) 286
— Jewell and McGee. (A.)..... 366
— Zerbe. (A.) 366
—Purifying and filtering feed water. Dougherty. (A.) 467
—Sterilization by ozone. Erlwein. (S.). 65
— (A.) 114
— by ozone *511
Water power 250
—Cost of development. Bell..... 301
Simpson 421
—versus producer gas. Nagel..... 145
—and electrochemistry in France. (S.). 115
Water-wheel governors. Lombard Governor Co. *162
Watt. James Watt Memorial 161
Watt-hour efficiency 212
Wehnelt interrupter. Houghton. (A.).. 114
Welding flux. Hout. (M.)..... 235
—Norman. (M.) 291
—Rails, tubes, etc. (See Aluminothermics.)
Westinghouse Co. Exhibit *380
—Machine Co. 210
Weston cell. Wolff 174
Carhart and Hulett *176

—Barnes and Lucas (S.) ... 202
Weston Electrical Inst. Co. Patent decision ... 333
—Exhibit ... 383
Whistle, electrically operated. Electrical Appl. Co. ... *332
Whitall Tatum Co. ... 210
White lead. Electrolytic preparation. Carrier ... 187
—Manufacture. Oettli. (A.) ... 465
Willard Storage-Battery Co. Exhibit ... 383
Wire. Heany's fire-proof. Easton ... 161
—of copper, electrolytically produced. (S.) ... 115
Wisconsin. Electrochemistry at University of. Burgess ... *189
Wood & Co., R. D. Exhibit ... 378

X

XENON ... 12

Z

Zinc:
—Metallurgy. Ingalls. (S.) ... 462
Developments in ... 337
—Electric furnace. Saigues (S.) ... 439
—Process of de Laval. (A.) ... *423
—Electrometallurgy. Hess. (S.) ... *457
—See also Furnace, Electric, Zinc.
Electrolyte. Nagel ... 64
Reduction. Nagel ... 392
Temperature of zinc oxide. Johnson ... *185
—in blast furnace by coal gas and natural gas. Nagel. (M.) ... 366
—Roasting furnace for zinc blends. Hoffman (M.) ... *44
from complex sulphide ores. Burleigh ... 357
from sulphide ores. Danckwardt (A.) ... 109
—from molten chlorides. Lorenz. (D.) 518
—from molten electrolytes. Guillaume. (D.) ... 518
—from ores by electrolysis. Envelop for anode, with ferrous sulphate solution. Laszczynski. (A.) ... 238
—from zinc chloride in acetone. Patten. (S.) ... 461
—for preventing corrosion of radiators. Kinnear. (A.) ... 153
—Sheet ... 252
Cleansing. Nelson. (A.) ... 166
Distillation. Temperature (S.) ... 322
—Electrolytic deposition ... 47
—and carborundum. Simultaneous production. Dorsemagen ... 7
—and lead from complex sulphides. Beadle. (S.) ... 155
—from molten electrolyte. Lorenz. (D.) ... 518
—Blende treated in electric furnace. Brown and Oesterle. (A.) ... 32
—Oxide and sodium nitrite. Kendall. (D.) ... 80
—Peroxide. Electrolytic production. Hinz (A.) ... 229
—Sulphides. Electrolytic treatment. Burleigh (S.) ... 318
—White. Manufacture. Oettli. (A.) .. 465
—Production of ... 121
—Electrodes. Structure. Job. (S.) ... 119
—Plating sheet zinc with nickel or copper. (S.) ... 348
—with nickel. Brandeley. (S.) ... 499
on iron. Grabrau (S.) ... 28
—Two stories of ... 252
—Copper alloys. Shepherd. (S.) ... 372
—Wheatley. (M.) ... 367
Zucker & Levett & Loeb Co. Exhibit ... 383

AUTHORS' INDEX.

ADDICKS, L. The rapid measurement of the conductivity of copper electrolytes 306

BANCROFT, W. D. The chemistry of electroplating 389
Bell, Louis. Power transmission for electrochemical works..... 301
Bennie, P. McN. Aluminium: a new process of M. Gustave Gin..... 138
——The electrical manufacture of steel. 20
Browne, David H. Apparatus for nickel and copper analysis 15
——What ailed the dynamo? 86
Burgess, C. F. Electrochemistry at the University of Wisconsin..... 189
——Electrolytic stripping of metals..... 8
——Electroplating upon aluminium..... 85
Burleigh, C. H. Electrolytic production of zinc and lead from complex sulphide ores 355
Butters, Chas. Electrolytic and zinc precipitation of gold from cyanide solutions 207

CABOT, G. L. Radioactivity..... 160
Campbell, Wm. On the micro-structure of metals and alloys..... 49
——Some notes on platinum and its deterioration 259
Carhart, H. S. American Electrochemical Society election..... 119
——The Daniell cell and the Gibbs-Helmholts equation 130
Carrier, C. F., Jr. The manufacture of sodium by the Becker process... 357
Collins, C. L., 2d. Adaptability of artificial graphite articles..... 277

DANNEEL, H. German Bunsen Society 277, 315, 360
Dixon, Clement. The metallurgy of gold on the Rand gold fields..... 215
Durant, H. T. Notes on the limitations of the cyanide process..... 107

EASTON, W. H. Fireproof wire..... 161
Ellis, Carleton. Flame regulation in chemical and metallurgical operations 495

FITZGERALD, Francis A. J. Electric furnace industries in 1903.... 6
——Materials for resistors..... 490
——Refractory materials 455
——Refractory materials in electric resistance furnaces 439
——Some first principles of electric resistance furnaces 342

GOLDSCHMIDT, Hans. The production of pure metals free from carbon by the aluminothermic method 145
Goodwin, H. M. The electrochemical laboratory of the Massachusetts Institute of Technology..... 264
Green, C. F., H. O. Hofman and R. B. Yerxa. A laboratory study of the stages in the refining of copper.. 87

HAANEL, E. Electrometallurgy of iron and steel..... 329
Hambuechen, Carl. Electroplating upon aluminium 85
Hamilton, E. M. A development in electrolytic precipitation of gold and silver from cyanide solutions 131
——Lead peroxide anodes for the cyanide process 372
Hofman, H. O., C. F. Green and R. B. Yerxa. A laboratory study of the stages in the refining of copper.. 87
Hunt, F. F. Electrolytic production of hydroxides and oxides..... 160
Hutchinson, Cary T. Electrical losses in an electrilytic copper refinery.... 13
Hutton, R. S. Preparation and compression of pure gases for experimental work 139

JOHNSON, W. McA. Arsenic in copper refining 207
——The theory of electrode potential... 97
——Uses of Acheson graphite in metallurgical research 345

KERSHAW, J. B. C. Aluminium as an electrical conductor..... 36

LENHER, Victor. The rare elements. 11, 61
Lorenz, Richard. Electricity direct from carbon 15

McCOY, W. A. A badge for members of the American Electrochemical Society 74
Magnus, B. Contact resistances and current leakages in an electrolytic copper refinery 74
Mailloux, C. O. What ailed the dynamo? 131
Marschall, Adolf J. Recent improvement in dry cells of the Leclanche type 63
Mott, W. R. Colloidial precipitation upon aluminium anodes..... 444
——Dimensions of the films on aluminium anodes 268
——The corrosion of aluminium and its prevention 129
——The electrical properties of the films that form on aluminium anodes 352

NAGEL, Oskar. Electrolytic zinc..... 64
——Producer gas and water power..... 145
——Reduction of metals..... 302
——Structure and tension..... 97
Neumann, B. Electric furnace methods in iron and steel manufacture, in comparison with the ordinary metallurgical processes 488
Noyes, Wm. A. The limits of physical science 498

OSTWALD, W. Electrolysis and catalysis 393

PERKINS, Frank C. Extracting gold and silver at Wallstreet Mills, Colorado 24
Petavel, J. E. Preparation and compression of pure gases for experimental work 139

REED, Chas. J. American Electrochemical Society election..... 37
——Fuel and heat batteries..... 18
——Solubility of gold..... 422
Richards, Jos. W. American Electrochemical Society election..... 74
——The present status of the electrochemical industries 5

SANDERS, W. M. The chemical engineer 292
Scholl, Geo. P. The manufacture of ferro-alloys in the electric furnace 349, 395, 449
Schoop, M. U. A contribution to the theory of the Jungner-Edison accumulator with constant electrolyte 272, 310
Scott, E. K. Refractory materials..... 454
Simpson, Louis. Cost of electric power used in electric reduction works. 421
Sjöstedt, E. A. Ferro-nickel from pyrrhotite 207

THATCHER, C. J. Some examples of catalytic action in electrolysis. 452
Thompson, M. DeK., Jr. Studies on the Siemens process for winning copper 225
Torrente, M. The metallurgy of gold on the Rand gold fields..... 215
Truesdell, A. E. Mercury cathode cell.. 119

WICKES, L. W. The relation between arsenic and electromotive force in copper-electrolysis..... 137
Winteler, F. Differences in the electrolysis of potassium chloride and sodium chloride 391
——Some notes on the uses of electrolytic chlorine 339
Wohlwill, Emil. Electrolytic refining of gold 221
——The electrolytic process of refining gold alloys 261

YERXA, R. B., H. O. Hofman and C. F. Green. A laboratory study of the stages in the refining of copper 87

Electrochemical Industry

VOL. II. NEW YORK, JANUARY 1, 1904. NO. 1.

Electrochemical Industry

Published on the first of each month by the

ELECTROCHEMICAL PUBLISHING COMPANY,

[*Incorporated.*]

114-118 LIBERTY STREET, NEW YORK.

J. W. RICHARDS, PH. D. .....*President.*
E. F. ROEBER, PH. D. .....*Editor.*

Telephone Call: 7607 Cortlandt.

Subscription Price: $2 per year, postpaid to any part of the world. Single copies 25 cents.

ADVERTISING RATES GIVEN ON APPLICATION.

Copyrighted, 1904, by the Electrochemical Publishing Co.

Entered as Second-Class Matter, June, 1903, at the Post-Office at New York, N. Y., under the Act of Congress, March 3, 1879.

CONTENTS.

Editorial 1
American Electrochemical Society 4
Metal Statistics 4
Second Meeting of the Faraday Society 4
The Present Status of the Electrochemical Industries. By Joseph W. Richards 5
Electric Furnace Industries in 1903. By F. A. J. FitzGerald 6
Electrolytic Stripping of Metals. By Charles F. Burgess 8
The Rare Elements. By Victor Lenher 11
Electrical Losses in an Electrolytic Copper Refinery. By Cary T. Hutchinson 13
Apparatus for Nickel and Copper Analysis. By David H. Browne 14
Electricity Direct from Carbon. By Richard Lorenz 15
Fuel and Heat Batteries. By C. J. Reed 18
The Electrical Manufacture of Steel (Process of Gustave Gin). By P. McN. Bennie 20
Extracting Gold and Silver at Wallstreet Mills, Colorado. By Frank C. Perkins 24
Synopsis of Articles in Other Journals 26
Analysis of Current Electrochemical Patents. By Geo. P. Scholl 32
Correspondence: Aluminium as an Electrical Conductor. By John B. C. Kershaw 36
American Electrochemical Society Election. By C. J. Reed 36
Book Reviews 36
Edison Nickel Iron Storage Battery 36
Acid Resisting Rings for Glover Towers 42
Centrifugal Machine for Chemical Laboratories and Factories 43
Industrial Notes 43
Digest of United States Patents, Prior to July, 1902. By Byrnes & Townsend 43

COMPLIMENTS OF THE SEASON:

We do not know how to start better the second volume of this journal than by presenting the compliments of the season to all our friends, and by extending our most sincere thanks to those who, by giving us their sturdy support, have made this journal, in a little more than a year, the representative exponent of electrochemical industries in America. On the title page of our first volume this journal is called "a monthly review of electrochemistry and electrometallurgy." From a friendly side we have heard a criticism to the effect that this journal should be, and has been, more than a mere review. While we have endeavored to give as concise and complete reviews as possible of what has been published either in the records of the Patent Office, or in other journals, yet the bulk of our editorial pages was devoted to the publication of original articles by authors who are building up the electrochemical industries. It is not often that a man who makes history cares to write it himself. But we are proud that in many cases we have overcome initial reluctance to publicity, and that the author's index of our first volume contains some of the best names in our industry and science. Some of them have been good enough to tell us that they support us, since they consider this journal to be their own journal; since they feel that this journal is conducted in the interest of the whole industry whose name it bears. The corps d'esprit of all the workers in various fields of electrochemistry and electrometallurgy has been the keynote of the success which this journal has met with so far; and it seems superfluous to add that we will not rest on our record, but will more than ever endeavor to increase the value of our pages to our readers. Then it may be that this journal, while being nothing but a technical newspaper, will become more than a review. In quite a number of cases we already know that information given in our columns has suggested to manufacturers valuable improvements, and has made people think of electrochemical methods who never thought of the same before. In this way, by the support of our friends, this journal may hope to do its share in aiding the development and progress of electrochemistry.

PROGRESS OF ELECTROCHEMISTRY

While the year 1903 has not brought any surprisingly new developments in electrochemical industries, yet there has been great activity in all fields, and much conscientious and useful work has been done. When the electric furnace came into existence, entirely new industries sprang up like the calcium carbide and acetylene industry, and the manufacture of carborundum and artificial graphite. No such startling developments are to be recorded in the last year, perhaps, with the only exception of silixicon and the introduction of electric furnace methods in the metallurgy of special steels. The main

progress in the electric furnace line during the last year was devoted to the design of furnaces for special purposes. This development is fully described in the suggestive article by Mr. FitzGerald, published in this issue, while the progress in electrolytic processes and especially in the manufacture of aluminium, sodium, caustic soda, bleaching powder, chlorates and perchlorates, and in the whole electrolytic refining, and in the electroplating field is fully recorded in the able and interesting review by Dr. Richards, also published in this issue. In that part of electrometallurgy which relates to the production of metals direct from the ores, no industrial advances have been made during the past year, although much experimental work has been done in this line. The process of Mr. David H. Browne for the electrolytic separation of nickel and copper from the Sudbury ores, which was operated with good success for several years in Cleveland, and the operation of which ceased, for commercial reasons, after the consolidation of the different nickel interests in one trust, will again be put into operation after the completion of the new and extended works being in course of erection in Canada. The process of Mr. P. G. Salom for producing lead from the ores by cathodic reduction is not yet operated on a commercial scale, but an important advance has been made by the design of his new cell, which makes the operation continuous. In the metallurgy of gold the use of the electric current for the precipitation of gold from cyanide solutions is still largely confined to South Africa, although much experimental work is done in this field in this country.

In the latest field of industrial electrochemistry, utilizing electric discharges through gases for producing chemical effects, the production of ozone from air and its use for sterilizing water is making headway in Europe, and the technical difficulties of the problem may be considered to have been solved. In view of the condition of the drinking water in many American cities, such processes should have a future in this country if the cost is not too high. The Bradley process for the fixation of atmospheric nitrogen is still in the stage of development. All the processes mentioned so far refer to the production of chemical effects by electrical means, while the reverse problem—the generation of electrical from chemical energy—covers the whole field of primary and secondary batteries. The most important development in this line is the appearance of the Edison storage battery on the market, on which we comment in another note. Concerning the old problem of electrochemists—the design of a carbon cell—this issue contains two articles. Prof. Lorenz' paper is especially valuable, on account of the lucid explanation of the thermodynamical principles to be considered in this problem, while Mr. Reed gives a very interesting critical analysis of the two latest attempts made by inventors in this field. The practice of estimating the growth and importance of applied electrochemistry by a review of the larger industries is, however, an underestimate of the services which that science is rendering. As Prof. Burgess points out in an article published in this issue, one should not neglect the numerous uses of electrochemical methods by which an economy of labor and materials is effected in various manufacturing industries. A striking example of such a saving is the method of electrolytic stripping of metals in the manufacture of bicycles described by Prof. Burgess. There can be no doubt that similar applications of electrochemical methods in other industries will greatly increase in future, as soon as the general manufacturer has learned that, as Dr. Richards puts it, electricity is such a kindly, such a manageable, such an all-potent agent, when its use is understood and mastered, that as a servant of mankind it may well be compared to the servant of Aladdin, the geni of the lamp.

EFFICIENCY CALCULATIONS

The usual method of calculating the energy efficiency of an electrochemical process is by comparing the energy required or given out, with the chemical energy calculated from the heat of reaction. In other words, we compare the energy required or produced by an electrochemical process, with the amount of heat which would be consumed or produced by the reaction if there was only an interchange of chemical energy and heat. We are, of course, at liberty to define the efficiency of a process to suit ourselves, but it may be interesting to point out that with the above definition we may occasionally arrive at very peculiar figures.

To take the case of a galvanic battery, what we want to get from it is external work in form of electrical energy. It is usual to consider that we get this at the expense of chemical energy. Hence, the above definition that the efficiency is the ratio of the electrical energy given out by the battery, to the heat which would be produced if the chemical energy, lost in the battery, would be changed completely into heat. If we neglect for the present the inevitable losses, due to Joulean heat, etc., the efficiency of a battery may have very different values. As examples, we may take the different batteries discussed by Prof. Lorenz in the introduction of his paper on electricity direct from carbon, published in this issue. In case of the Daniell cell the efficiency, as above defined, is practically 100 per cent—because the chemical energy of the reaction in the Daniell cell is completely changed into electrical energy.

In the zinc-silver cell, which is Prof. Lorenz' second example, the efficiency, as defined before, is 90.2 per cent, because this cell, while being discharged, tends to heat up, so that if the discharge is to go on at constant temperature—which is the first supposition of the application of thermochemical data—the cell must give off heat to the outside. In other words, the chemical energy lost in the cell is changed partly into electrical energy, and partly into heat; the electrical energy produced is, therefore, necessarily smaller than the chemical energy lost and the efficiency is below 100 per cent. In the third example of Prof. Lorenz—the lead-copper cell—the efficiency, as before defined, is 127 per cent. The reason is that the cell, while giving out current, tends to cool, so that in order to discharge it at constant temperature, we must supply heat from the outside to the cell and we have a change of both chemical energy and heat into electrical energy. The electrical energy produced is in this case necessarily greater than the chemical energy lost, and the efficiency, as defined above, is above 100 per cent. Even if we take into account the losses due to Joulean heat, etc., we may get, in a cell of this

type, an efficiency of over 100 per cent, as long as we define it by the ratio of electrical to chemical energy. But in practice we would have to heat the cell artificially, in order to keep its temperature constant and this heat would cost money. The efficiency is a practical item; we want to know what we put into a process, and what we get out of it. In the present case we do not only lose chemical energy, but have also to supply heat.

Still more peculiar and more interesting is, however, the last example of Prof. Lorenz, in which he shows that an endothermic process may be used for the generation of electrical energy in a battery. An endothermic process has a negative heat of reaction, and in a cell of this type, while it is discharged at constant temperature, heat is supplied from the outside to the cell, and is partly changed into chemical energy, and partly into electrical energy. In this case it would be evidently foolish to try to use the term efficiency for the ratio of the electrical energy produced to the chemical energy produced.

These examples indicate that it would be preferable to drop the above definition of the efficiency of an electrochemical system, and to define the efficiency rather as the ratio of the electrical energy which is produced to Helmholtz's "free energy" of the system. The latter quantity—not the heat of reaction—represents the maximum amount of external work which a reaction can perform. Hence, this definition of efficiency would give us exactly what we want to know: how much useful electrical energy we get in percents of the maximum amount of useful external work which it is possible to get under ideal conditions. The former definition of efficiency is essentially based on the assumption that Thomson's rule is correct, while the latter definition is based on the more exact Gibbs-Helmholtz equation. We know that at ordinary temperatures Thomson's rule is practically correct in the great majority of cases, but the higher we go up in the temperature the less exact it becomes, and the greater becomes the term of correction which distinguishes the Gibbs-Helmholtz equation from Thomson's rule. At the temperature of the electric furnace, calculations based on Thomson's rule might lead to absolutely wrong results, and for furnace calculations the efficiency based on the "free energy," instead of the heat reaction, seems very desirable. Of course, the trouble is that we have not such extended determinations of the free energy of a reaction, as we have of the heat of reaction. It seems a very promising field for research to determine systematically the free energy of all possible reactions in the same way as Thomson and Berthelot measured the heats of reaction, although it cannot be denied that the difficulties seem to be even greater than in the latter case.

EDISON NICKEL-IRON BATTERY

Since the celebrated Edison nickel-iron battery has now made its somewhat belated appearance on the market, a brief summary of its distinguishing features may be of interest. From the description of the battery published in this issue, it appears that the capacity figure given by Dr. Kennelly in his original announcement of the battery in a paper read on May 21, 1901, and derived from tests with simple experimental cells—namely, 14 watt hours per pound—has exactly been reached again in the latest type of commercial cell, while the first commercial cell placed on the market had a somewhat smaller capacity. Besides its high watt-hour capacity per unit of weight, the capability of the Edison battery to stand very high rates of discharge or charge is of extreme importance. In this respect Prof. Hospitalier's comparative curves for the Edison battery and the lead accumulator, published in this issue, are highly interesting. With respect to durability the construction of the Edison battery is very assuring, being made, with the exception of the active mass, all of nickel-plated steel. The use of a stiff and easily worked metal for the support plates and the packing of the active mass in perforated pockets with stiff covers should prevent the battery from being deteriorated to the same degree as the lead accumulator. In the mechanical perfection of his battery Mr. Edison's inventive ingenuity and mechanical skill have certainly achieved one of their greatest triumphs. While concerning durability and strength the use in practice has, of course, the last word to speak, yet the results so far obtained look very promising, and it cannot be denied that in the mechanical construction of his cell Mr. Edison has endeavored to render it as fool-proof as possible. Of course an oxygen lift cell can be more easily perfected in this respect than the lead accumulator, which, as someone once said, will always need more or less nursing during use.

Considered from an electrochemical point of view, the main feature which distinguishes the Edison battery from the lead cell is to be found in the role which the electrolyte plays in the reaction. In the lead accumulator the electrolyte is really an active reagent, because it undergoes change during charge and discharge, sulphuric acid being consumed during discharge, and produced during charge. A certain number of ampere hours requires necessarily a certain quantity of sulphuric acid. On the other hand, in the oxygen-lift cell the electrolyte, as a whole, is not changed. The change of the dilution of the electrolyte in the pores of both plates of the lead accumulator during discharge, is the principal reason for the drop of voltage during discharge; this is especially important at high discharge rates, when the acid is quickly diluted in the pores of both plates with a resulting rapid drop of voltage, as though the whole solution had been diluted to the same degree. On the other hand, it seems probable that in the Edison cell for average discharge rates the slight gradual drop is mainly due to an increase of internal resistance. There is a tendency of local concentration increasing in the one plate and decreasing in the other, but the drop of e. m. f. due to these local concentration changes is small, in accordance with the theory. In the curves of the Edison cell such a drop of voltage clearly manifests itself only at the highest discharge rate; this indicates that the active masses are sufficiently porous for average discharge rates. While the position of the lead accumulator seems secure for electric station work—at present estimated at about 75 per cent of the total storage battery output—the features of the Edison battery, pointed out above, should make it especially suitable for automobile purposes, and now that Mr. Edison's battery has finally been placed on the market, we may hope that this will mark the beginning of a new era in electric automobilism.

AMERICAN ELECTROCHEMICAL SOCIETY.

The next general meeting of the American Electrochemical Society will be held in Washington, D. C., on April 7, 8, 9.

The following gentlemen will be elected members at the January meeting of the Board of Directors: J. T. McNaier, Philadelphia, Pa.; Kenneth B. Quiman, Somerset, W., Cape Colony; G. L. Townsend, Washington, D. C.; Henry M. Loomis, Niagara Falls, N. Y.; Orion Brooks, San Francisco, Cal.; Charles A. Marie, Paris, France; P. L. T. Heroult, La Praz, France; G. Orth, Nancy, France; Fred. L. Shinn, Madison, Wis.; A. Gandillon, Geneve, Switzerland; O. Solvay, Brussels, Belgium; Louis A. Herdt, Montreal, Canada; William Stanley, Great Barrington, Mass.; Edwin J. Prindle, Washington, D. C.; H. M. Fernberger, Niagara Falls, N. Y.; Frederick Conlin, Bethlehem, Pa.; William L. Dudley, Nashville, Tenn.; Henry P. Talbot, Boston, Mass.; Raymond Outwater, Washington, D. C.; Darragh de Lancey, Great Barrington, Mass; Ernest R. Barrows, Brandt, Pa.

METAL STATISTICS.

The latest volume of the Comparative Statistics of Lead, Copper, Spelter, Tin, Silver, Nickel, Aluminium and Quicksilver has recently been issued by the Metallgesellschaft and Metallurgische Gesellschaft A-G. of Franktort-on-the-Main, Germany. We are obliged to Dr. Franz Meyer, New York City, for a copy of this volume. It contains a great number of statistical tables on the production and consumption of the metals mentioned, in the different years between 1893 and 1902, with some notes on the development during 1902.

The world's production of *lead* in 1902 is given as 863,000 tons, and has, therefore, increased by 24,000 tons, while in 1901, it only increased about 6,000 tons. This increase in the production is all the more remarkable, as four mines in the Broken-Hill district in Australia had to stop working in consequence of the low price of the metal, which caused a falling off of the production to the extent of 25,000 tons of lead.

According to calculations which comprise the produce of the smelting works, the world's production of *copper* amounted to 533,000 tons in 1902 (while H. R. Merton & Co., of London, give it as 550,000 tons). This is an increase of about 3 per cent over the preceding year, which is entirely due to the United States of America, where the production from home material has risen from 271,000 to 363,000 tons

The world's production of *spelter*, which already showed the considerable increase of 29,000 tons = 6 per cent in 1901, has again increased, in 1902, by further 38,000 tons = about 7½ per cent, thus reaching the figure of 545,000 tons. The increase is chiefly due to the United States, Great Britain and Upper Silesia (Germany).

The production of *tin* amounted to 88,300 tons in 1902. In the United States, in consequence of the favorable position of the tin-plate industry, the consumption rose by more than 10,000 tons to 39,300 tons, thus amounting to 45 per cent of the world's production.

The world's production of *nickel* in 1902 is given as 8,335 tons, of which 4,715 were produced in the United States and Canada.

The production of aluminium is given as 8,111,000 kg. in 1902 (against 7,810,000 in 1901, 1,426,760 in 1895 and 333,307 in 1891). The variation of the price of one kilogram of aluminium is seen from the following data: $250 in 1855, $17.50 in 1886, $6.90 in 1890, $1.00 in 1894, $0.50 to $0.62 in 1900 to 1902.

SECOND MEETING OF THE FARADAY SOCIETY.

The second ordinary meeting of the Faraday Society was held on December 8, in the library of the Institution of Electrical Engineers, in London. Prof. A. K. Huntington presided.

Dr. Lehfeldt gave a short résumé of his paper on "The Total and Free Energy of the Lead Accumulator," which was already noticed in Electrochemical Industry, vol. I., page 413. The most convenient form in which to express the concentration of acid in the accumulator, for the present purpose, is by the molecular function (Z) of H_2SO_4. The heat of the reaction (in equivalents)

$$\tfrac{1}{2}Pb + \tfrac{1}{2}PbO_2 + H_2SO_4 = PbSO_4 + H_2O$$

may then be put in the form—

$$h \frac{dQ}{dZ}$$

where h is the heat of reaction between the pure materials (in absence of water) and Q is the heat of formation of the mixture $Z.H_2SO_4$ $(1 - Z)H_2O$. Numerical values of this are calculated from the experimental data already in existence for the range $Z = 0$ to $Z = 0.25$, and the results shown by a curve. The free energy can be put in a similar form. A curve is drawn for it, based on e. m. f. measurements, and the latter are compared with the vapor pressures (p) of dilute H_2SO_4 by the relation which must exist between these quantities, according to the principles of thermodynamics.

Dr. Ogg sent in a short note, in which he tested the numbers derived from Thomsen's formula, and compared them with those derived from Pickering's experiments. The former all lie below the latter, probably because the Thomsen formula does not absolutely represent the heat of mixture of H_2SO_4 and H_2O.

Dr. Lowry made some remarks on the basis of the sulphate theory, observing that sulphating is usually looked upon as a "disease."

Dr. Lehfeldt, in his reply, said that the adoption of the sulphate theory is justified by the fact that measurements of the changes of weight in the Pb, PbO_2, $PbSO_4$ and H_2SO_4 agree tolerably closely with those deduced from the equation given in the paper. Sulphating, however, in the sense used by practical men is not the same as the formation of sulphate during discharge, where only a film is allowed to form, and is immediately broke down by the current during charge.

Mr. J. A. Sutherland then read a paper entitled "Bitumen in Insulating Compositions" (Part I.). The author points out that little or no reliable data have been published, as to the use of bitumen for electrical purposes. The chief source of bitumen is Trinidad Lake, where there is estimated to be a quantity of nine million tons, which appears to be renewed to the extent of 20,000 tons annually. Upwards of 150,000 tons are exported yearly. Bitumen is also found in Venezuela, California, and on the shores of the Dead Sea; it occurs in some limestone (asphalt) as an impregnation, about 10 to 15 per cent being present, but it does not pay to extract it from this source. Its physical and chemical properties and constitution, which are fully dealt with in the paper, prove it to be infinitely superior to gas or coal tar for insulation and durability. Care should be exercised in refining; the temperature should be regulated, or the results will be injurious, both for paving and electrical purposes. It is used in cable insulation, and very extensively for joint boxes and troughs for "solid laid" cables. No specification is, however, in use, and the object of this paper is to invite discussion and the views of electrical engineers to assist the author in the completion of his experiments, and to enable him to draw up a satisfactory definition of bitumen, so that users may secure the best results from its valuable non-hygroscopic and insulating qualities.

Gaster referred to Roumanian sources af asphalt. He has succeeded in freeing pitch from its carbon, which can then be used for arc carbons and electrodes, but the pitch still retains too much oxygen to be a satisfactory substitute for bitumen.

Dr. Steinhart strongly supported the author in his remarks regarding the desirability of arriving at some standard tests for bitumen. Physical, as well as chemical and electrical tests are required. E. Kilburn Scott said that some firms declare that refined pitch is as satisfactory as bitumen.

THE PRESENT STATUS OF THE ELECTROCHEMICAL INDUSTRIES.

BY JOSEPH W. RICHARDS, PH. D.

Almost without exception, the present is a time of growth and expansion in this industry. Most of us can remember without trying very hard, the time when electrochemistry, as an industry, included silver and gold plating, and the electrorefining of copper. It is hard to realize that the first electrolytic copper refining plant in this country is not twenty years old, and yet now we are producing eighty-five per cent of all the electrically refined copper made in the world. The last twenty years have been practically years of the creation of industries, no one knew or could even guess what the next monthly journal would record as a new factor in industrial electrochemistry.

Untiring experiment, unwearying endeavor, undaunted application, and many unsuccessful enterprises, have marked the path and the development of these twenty years. But, one by one, the commercially successful schemes have gained a footing, little by little they have gotten onto firmer ground, and now there exists a large grove of flourishing industries, in the midst of a healthy growth of promising saplings, which may soon grow into big oaks themselves. Competent observers, not themselves electrochemists, have noticed this development, and have published their testimony to the fact that this branch of industry is the most rapidly advancing one in the catalogue of the applied sciences.

Such a condition attracts not only attention, but also enlists co-operation. Our young men ask their friends what is the best thing for them to go into, and an increasing number are referred to electrochemistry. Nothing succeeds like success, the saying goes, and the successful industry attracts capitalists, promoters, business men, technologists of every description, and also attracts the interested and enlists the assistance of scientists in general.

The present status is, all things considered, a healthy and a promising one. None of the industries seems to have reached its limit of progress or improvement, none is at a standstill, and many are continuing the inroads they are making in established non-electric methods.

The production of the alkaline metals cheaply by electrolysis has superseded all other methods, and the field of use for these metals is rapidly extending. Within a year the production of metallic sodium at Niagara Falls has been doubled. The largest use is probably for making sodium cyanide for the cyanide process of treating gold ores, and since the latter is extending with considerable energy, there are bright prospects for the extension of the sodium industry. Renewed efforts are being made to use sodium as a reducing agent in metallurgy, and some simple devices may render this use practicable.

The production of alkaline salts from the cheap alkaline minerals is also progressing apace. In the manufacture of caustic soda and bleaching powder from common salt, the electrochemist has come into direct competition with one of the best established and technically the best-developed of the chemical industries. The war has been strenuous, but the non-electric industry is now practically at the mercy of the electrolytic processes. It is estimated that in England alone forty million dollars of invested capital has been concerned in this defeat of an established industry. The victors, however, have begun quarreling over the spoils, the rival electrochemical plants have cut the prices of their products down to such a degree that it would appear at present that the only hope for the industry is a mutual understanding by which competition may be regulated within reasonable bounds, and the electrochemists thus get the reward of their labors. In this strife, it appears to the writer that while the aqueous mercury processes have so far been the most successful, that they have probably reached nearer to their possible ultimate perfection than the diaphragm or the fused-bath processes, and that the latter, being susceptible of greater improvements, will, in the future, hold their own quite as well, if not better than before, in competition with the mercury processes. The alkaline chlorate industry is already conquered for the electrolytic methods, the non-electric processes have fled the field. It is, therefore, with them, a question of supply, demand or proper production to make a profitable business. The manufacture of other alkaline salts, such as bi-chromates, permanganates, etc., is already being undertaken, mostly by the chlorate manufacturers, who are looking for new worlds to conquer.

The manufacture of electrolytic bleach is increasing in extent and importance. This branch of electrochemical science is particularly useful to the extension of the industry in that the multiplication of small electrochemical plants in numerous localities serves to excite a widespread interest in electrochemical methods, gives facilities for experiment to many would-be electrochemists, and thus paves the way for further advances, while the saving over non-electric bleaching preaches a loud sermon to the capitalist.

The electric plating industries are our pioneer electrochemical industries, and while we may not say that they are increasing in importance, like the other sister industries, yet there is no doubt that the activity and spirit of research, and particularly the spirit of scientific exactness which is ruling in other electrochemical arts is reacting very favorably towards the obliteration of old rule-of-thumb traditions and mediæval practices, and the substitution therefor of accurate measurement and control. When all the conditions are known, and quantitatively controlled, they can always be produced with exactness, and such terms as luck, good-fortune or mystery go out of the back-door. Abundant signs of this awakening have been shown this year in the plating industries; some of our most prominent electrochemists have given their best attention to the subject, many timely articles have appeared in the journals and scientific transactions, and the plating business of the future is very evidently going to pass into the control of the wide-awake men who keep fully abreast of the scientific advance of the times.

The copper refining industry is advancing splendidly. One particular characteristic is the different avenues of advance in different parts of the country. One large plant in the East goes back to the almost discredited series system, claiming that, as they have improved it, it is better than the parallel system. Another huge plant out West uses the high current density of 40 amps. per square foot, while its neighbors, forty miles away, not blessed with such cheap power or such pure anodes, keep pegging away at 12 amps. One plant removes its cathodes every four days and melts them down, another every two days and strips them, while a third, knowing exactly what his competitors are doing, keeps his in a month. These variations in practice are of the opposite significance to what they would have been ten pears ago; then they would have meant that each stuck to his own method largely from inertia; now they mean that each has convinced himself, by trying all the other schemes, that his is the best under the conditions in which he is working. The industry has been described by Mr. Ulke, in his book on Electrolytic Copper Refining. Prof. Bancroft has contributed an article which, in spite of what his critics have said, is a most valuable contribution to the science of electrolytic refining of copper, and the records of the other scientific journals and of the patent office testify to the continual advance of this industry, all branches of which are feeling the stimulus towards higher efficiency and reduction of costs.

The electrolytic refining of lead bullion has all at once flashed up among us, not as a proposed method, but as a good-sized plant already in commercial operation. The event is something akin to the birth of a baby ten years old. How often we have admired the pluck of Dr. Keith, trying thirty years ago to solve the same problem, and how often the question has been since attempted, but now Mr. Betts, with his

almost unknown electrolyte, fluo-silicate of lead, shows us how easy the thing is to accomplish when you once know how. A recent newspaper item stated that 60,000 ounces of silver from his plant at Trail, B. C., had just reached the San Francisco assay office, and that the refining plant was in process of being multiplied by three. The results of the working of the plant have been reported in a most scientific manner and with most commendable frankness, to the scientific journals, thus increasing the debt which electrochemists owe Mr. Betts and the admiration which they feel for him and his work. When experience has been gained at this plant, there is no reason why this method of refining should not spread among the lead refineries like measles in a kindergarten. Wherever coal is dear and power cheap, there is the opportunity for the electrolytic method to get a foothold. I know of no more encouraging chapter in the history of electrochemistry, for the perusal of our coming workers, than to study the rise and development of Mr. Betts' process. It is fascinating, and an epitome of what may happen in scores of other industries when the educated and capable electrochemist gets fairly and actively to work at them.

One of the oldest electrochemists in America has under his charge one of the newest electrochemical refining processes. Dr. Tuttle, of the Philadelphia Mint, has described very clearly how he is operating the Wohlwill process of refining gold, and the information is very welcome. With the successful working at Philadelphia as a start, we may expect other plants at Government and private establishments to get into operation, and thus another electrochemical industry to take its place in the galaxy of recent achievements. Every successful new process, when properly and completely described, is a sermon to the electrochemist on how difficulties have been overcome, and gives him training in meeting the novel difficulties of his own special problems. Thus, when gold chloride alone is used as solution, only a fraction of the gold is dissolved from the anode which the current should dissolve, but by acidulating strongly with hydrochloric acid, the normal amount is dissolved. Betts found something similar with lead and hydrofluoric acid. The knowledge of these facts helps every electrochemist and electro-plater, and has in no wise injured the givers. May we have a healthy growth of this spirit of mutual helpfulness among American electrochemists; it is really this which is sending us ahead of the rest of the world.

The electric de-tinning of tin scrap has finally found a lodgement in the United States, and it is to be hoped that we have seen the last of that humiliating spectacle of shipments of tin scrap from Baltimore and New York to Hamburg. Like the tin-plate industry, once here we believe it is here to stay, and the Staten Island plant will be an object lesson in how to treat such material which will probably soon lead to the similar treatment of all kinds of metallic scrap which needs un-plating.

The two thousand words which the editor asked me to write on my topic are already written, and, as nearly as I can estimate, five thousand more would be necessary to do equal justice to all the electrochemical industries as yet unmentioned. Therefore, we must be brief.

The electric manufacture of pig iron is a scientific possibility but commercially impossible; the electric manufacture of steel, by any of half a dozen proposed ways, is not only practical but practicable, and already in use for manufacturing a high-grade tool-steel, where power is cheap and fuel dear. It is the writer's belief that the days of crucible steel are numbered; that is, the maker of electric steel may still call his product "crucible steel," to help sell it, perhaps, to those who have all their lives asked for crucible steel, but when the electric steel furnaces are perfected a little more, the costly crucible, with its 60-pound charge, will be a back-number. This branch is distinctly in a transition state, but developing rapidly, and a few years will see a fixed electric steel-furnace practice replacing most of our crucible steel plants.

Aluminium has come through a tempestuous year in some respects, the pending litigation and uncertainty of its outcome unsettling both the producers and consumers. The faith of the manufacturers in the future demand for this latest of commercial metals is shown by the increase of the capacity of the lower Niagara works by 3,000 hp, which together with the starting of operations at Massena gives this company something like 22,000 hp now in operation, or double the sum of all its European competitors. The uses for the metal are growing apace, and the writer abates not one jot of his conviction that the next generation will see aluminium one of the most common metals in every day use, and selling at a price which will make it practically the cheapest metal next to iron. This year has seen substantial advances toward that goal.

The electric manufacture of calcium carbide, carborundum, manufactured graphite, artificial emery, phosphorus, electrolytic vanillin and carbon-bisulphide, have all flourished during the year. Those of the electric reduction of lead ore, production of nitric acid from atmospheric air, manufacture of barium compounds and several others have been more or less sucessful, and all promise well for early development into successful commercial enterprises.

Besides the full-grown and the developing, there are also the prospective processes and industries, whose consideration would alone make a long chapter. Electrochemists have only scratched the surface of the possibilities of applied electrochemistry. Like the philosopher, they have been picking up pebbles on the sea shore, and a whole ocean of possibilities lies before them. Electricity is such a kindly, such a manageable, such an all-potent agent, when its use is understood and mastered, that as a servant of mankind it may well be compared to the servant of Alladin, the geni of the lamp. Each passing year is destined to record an increasing catalogue of its beneficial services, and each year will increase the interest and the fascination of the subject to live electrochemists.

ELECTRIC FURNACE INDUSTRIES IN 1903.

By F. A. J. FitzGerald

A review of industries using the electric furnace, for the past year, does not show any remarkably novel developments; but there has nevertheless been great activity in this field, more especially in the designing of new furnaces. The majority of these are still in the experimental stage, but may eventually become of commercial importance, while many others obviously will not survive. Anything approaching a complete review of the work done in electric furnaces during the past year would be altogether impracticable in a limited space, and therefore it will only be possible to glance at a few examples which are instructive as indicating the probable direction of future developments.

One of the most interesting branches of electric furnace work in Europe is that of the manufacture of ferro-alloys and steel. It is curious to note here that, notwithstanding the fact that the United States is to-day the largest producer of iron and steel, large quantities of ferro-alloys are still imported from abroad.

The work of Keller, of Keller, Leleux & Co., at Livet, France, is of particular interest, and has been very fully described by Mr. Keller* in his paper before the *Iron and Steel Institute*. His company is at present using about 2800 kw in the manufacture of ferro-alloys, special grades of steel and copper. In the Keller furnace the hearth is not used as one of the electrodes, the current passing from one electrode, through the charge to the other electrode. By using two or more pairs of electrodes it is possible to make the working of the furnace continuous, as one pair of electrodes may be changed at a time. Another important feature of this design is that by making an arc between the electrode carbons and the charge, the contamination of the metal by carbon is said to be avoided.

*Electrochemical Industry, 1903, pages 420 and 162.

The Héroult process for the manufacture of steel has some features in common with Keller's furnace, two electrode carbons being used and the current passing through the bath from one to the other. In the furnaces designed by Stassano and Chavarria-Contardo, however, the principle is different, for in them the material under treatment is heated by radiation from an arc.

In Kjellin's process a totally different principle is made use of, the material treated forming the secondary of a transformer. This process is interesting, and is said to be very satisfactory; but it has not yet been worked on a sufficiently large scale to demonstrate its commercial value.

The Kjellin furnace is of the resistance type, and from its principle avoids altogether the use of carbon electrodes and the consequent introduction of carbon from that source into the metal.

Gin in his latest process, described elsewhere in this issue of ELECTROCHEMICAL INDUSTRY, uses a furnace in the form of a long, narrow channel, the terminals consisting of large reservoirs, where the metal is kept in the solid state, thus furnishing the furnace terminals.

Girod is designing crucible furnaces in which the crucible is surrounded by a resistance material through which the current passes. His company, La Société Anonyme Electrométallurgique, has works, or is about to start works at various places, Albertville and Ugine (Savoie), and at Courtepin (Switzerland). In the latter place 4000 kilowatts will be employed. A great variety of products are manufactured: ferro-alloys of silicon, molybdenum, tungsten, chromium, vanadium, etc.

In Europe more attention seems to have been devoted to the application of the electric furnace to the metallurgy of iron than to any other process, since the days of the calcium carbide boom. Some work has been done on its use in the manufacture of glass, but this difficult problem does not as yet seem to have been solved commercially.

Some interest was excited by a resistance furnace designed by Dorsemagen, for the simultaneous production of carborundum and metallic zinc from silicious zinc ores; but it is quite safe to say that the furnace, as described in the patent, could not possibly be worked commercially.

Turning, now, to this country, it will be noted that, as in Europe, much work has been done in the application of electric furnaces to processes in which relatively low temperatures are required. In a furnace patented by Acheson, the purpose is to heat materials between definite limits of temperature. In most of the electric furnace processes of earlier days the object was to raise a mass of material to a very high temperature, and the question of temperature regulation was not of the first importance. In Acheson's work on carborundum manufacture, he found that above a certain temperature his product was decomposed, and hence he designed a new form of electric furnace, in which the temperature could be regulated. However, in the carborundum furnace the permissible range of temperature is great, or in other words, the difference between the temperatures of formation and decomposition of carborundum is considerable. In the process of the manufacture of carborundum an amorphous substance of a greenish color is first formed, and the temperature limits in this case lie very close to one another. To manufacture a substance of this description, the furnace must be so designed that very accurate temperature regulation is obtained. To accomplish this result, Acheson built his furnace with several cores, which carry the current, and are thus maintained at the upper limit of temperatures, while the cores are so placed, relatively to one another, that the points of lowest temperature between them are at or above the lower limit.

Acheson uses this furnace for the production of a series of silicon-carbon-oxygen compounds which he has named "siloxicon." The material has a very refractory nature, and is said, in certain experiments made on a large scale, to have proved satisfactory; which encourages the hope that it will prove of value in other places. So far, about 130,000 pounds of the material have been manufactured.

In a process recently patented by F. J. Tone, is found another example of a furnace constructed in such a way that careful temperature adjustment can be obtained. This process is for the reduction of oxides whose temperature of reduction lies close to the temperature of volatilization of the reduced substance. The furnace is of the resistance type, the heating body being composed of a vertical column of carbon blocks piled together and forming electrical connection between the upper and lower terminals. It is said that the results obtained with this furnace in the production of silicon are very satisfactory.

A further example of the use of electrical furnaces for relatively low temperatures is found in Hall's process for the baking of carbon electrodes, and his process of removing silica from coke. The unbaked electrodes are arranged about a central core of conducting material, and a current passed through the core, which raises it to a high temperature. The heat thus developed bakes the electrodes at a "temperature higher than that ordinarily obtained in gas furnaces." While it is difficult to understand how a uniform baking of the carbon electrodes can be obtained by the method as described in the patent specifications, it is interesting as an example of the application of the electric furnace to temperatures very little higher than those obtained in fuel furnaces.

The manufacturers of calcium carbide, the largest users of electric furnaces, have not apparently made any radical changes in their furnace practice. The Carborundum Company expects to use 5000 hp in electrical furnaces next year, and will have a 2000-hp furnace, without doubt the largest resistance furnace that has ever been constructed.

It would be impossible to review even briefly the numerous patents that have been taken out for various types of electric furnaces, but it may be noted that a study of recent developments in this direction reveals the growing interest in furnaces of the resistance type.

As regards the future of the electrical furnace, two important considerations must be kept in view. Before the advent of the electrical furnace, the maximum temperature attainable in industrial processes was somewhere between 1500° and 2000° C.; but now a maximum temperature between 3500° and 4000° C. may be obtained. Thus the manufacturer now has at his disposal a great range of temperatures hitherto unattainable.

The second point to be considered is that in transferring heat from one body to another by conduction, the rate of transference varies directly as the difference of the temperatures of the bodies. In certain processes, where fuel is used as the source of heat, the temperature which it is desired to reach differs but little from the temperature of the source of heat. Here the expenditure of energy is necessarily very great, on account of the long time required to obtain the temperature desired at the end of the run.

Both these considerations are now claiming the attention of inventors. In the earlier days of electric furnaces their use was devoted exclusively to such processes as the manufacture of carborundum, calcium carbide, graphite, etc., where very high temperatures unattainable by other means are required; but now the electric furnace is being used for processes requiring temperatures that lie in the region between the temperatures of burning fuel and the electric arc. Such processes are illustrated by Tone's method of manufacturing silicon, Acheson's manufacture of "siloxicon," and the furnaces of Keller, Girod, Harmet, Héroult and others for the production of certain ferro-alloys.

But in addition to this we find the electric furnace also applied in processes where the necessary temperatures are not above those attainable by other means. Keller, Héroult, Gin, Stassano, Chavarria-Contardo, Kjellin, in Europe, and Ruth-

enburg in this country propose to use electric heat for the production of iron and steel; Hall uses the electric furnace for baking electrodes at temperatures that cannot easily be obtained in gas furnaces; and various other inventors, too numerous to mention in detail, are experimenting with the electric furnace at temperatures that represent the limit that can be reached by other means.

It seems probable that before long there will be new industries undertaken to develop processes requiring those temperatures which lie between the temperatures attainable by ordinary means, and that of the electric arc. In certain processes where very high temperatures that cannot be obtained by means of burning fuel are not required, it may be expected that the electric furnace will find a place, on account of the great economical advantages in the use of electricity, where these lie in the possibility of generating the heat at the place where it must be used, or in the high temperatures that may be given to the heating mass.

Finally, it does not seem unreasonable to look for the use of the electric furnace as an auxiliary to furnaces of other kinds, where a point is reached at which the attainment of high temperatures can be most economically reached by electrical methods.

ELECTROLYTIC STRIPPING OF METALS.

By Prof. Charles F. Burgess.

A number of years ago, when the manufacture of bicycles was in its most prosperous stage, an important department in each factory was that devoted to filing, where the thin layer of brass on the surface of the frames was removed by a corps of workmen stationed at benches around the room. The trouble and expense incurred in maintaining this department induced the manufacturers to seek a relief, which was found through the agency of the electric current. As a result, the filing room was changed to an electrolytic stripping room, which was free from labor troubles, and in which the work proceeded more quickly, cheaply and satisfactorily than had been possible previously.

The common practice of estimating the growth in importance of applied electrochemistry by a statement of the values of the products manufactured is an underestimate of the service which that science is rendering. It neglects many uses to which the electric current may be put to effect an economy of labor and materials in various manufacturing industries. A striking example of such a saving is that to which reference has just been made in connection with the manufacture of bicycles.

In assembling bicycle frames the method of brazing the joints which formerly was most commonly used, consisted in dipping them in a bath of molten brass, thereby leaving upon a portion of the surface a thin film of brass which it was necessary to remove in order to apply a suitably adherent coating of enamel. The method by which this was first effected consisted in filing the exterior brass. This was uneconomical, as it entailed a cost for labor of about twenty-five cents for each frame. Moreover the frame was weakened as a result of removing a portion of the steel. With the thin steel tubing which was used, the removal of even a slight amount of the material meant a considerable loss in strength, and slight carelessness or lack of skill on the part of the workman became a matter of no small moment.

An idea that then naturally suggested itself was to remove this brass through the dissolving action of certain chemicals. Among materials which were tried, but which produced only partially satisfactory results, were potassium cyanide and sodium or potassium bichromate solutions. The slowness of the action and the large consumption of chemicals made necessary prevented this from becoming a practical solution of the problem, and the next attempt was the use of the electric current to aid in the solvent action. This produced satisfactory results, as stated previously.

Although this process has been in use for a number of years, it has received little or no attention in technical publications, so that a somewhat detailed description may be of interest. The removal of the brass from the iron is effected in the manner known by the plater as the "electrolytic stripping process," in which the current is made to corrode the surface material without injuring the underlying metal. Inasmuch as there are only a few grams of superfluous brass on each frame, and somewhat evenly distributed, it would appear that the application of a suitable stripping solution might be a simple matter, but difficulties were encountered in finding practical electrolytes. These arose from the fact that when a number of different metals are in contact, and are used as the anode, the tendency is for the most electropositive metals to corrode the more readily. In the case under consideration, we have a combination of zinc,

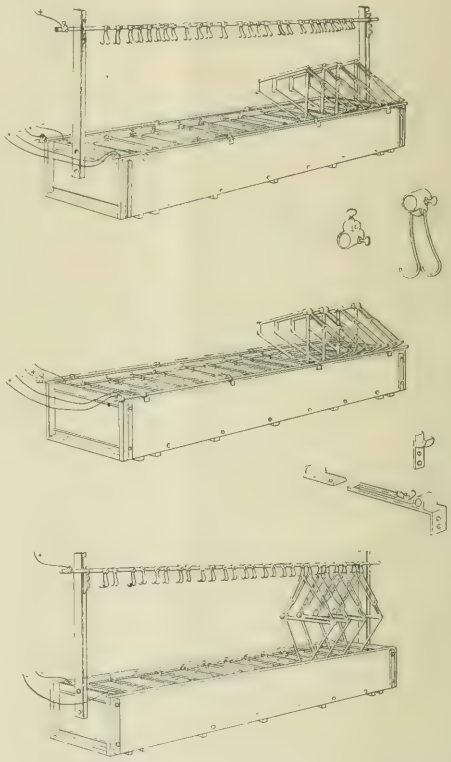


FIG. 1.—TANKS AND FITTINGS FOR STRIPPING BRAZED BICYCLE JOINTS.

iron and copper whose positions in the electrochemical series are in the order given, and the zinc is the metal that is the most readily soluble of the three. The dissolution of a small amount of zinc from the brass leaves a copper surface, which is electronegative to the iron. This brings about a tendency for the iron to be corroded before the copper. In an experimental investigation of this problem, undertaken in the laboratory of Applied Electrochemistry of the University of Wisconsin by Mr. M. C. Beebe and the writer, a large number of electrolytes were tried, but none would cause a corrosion of the brass, while leaving the iron uncorroded. It was found, however, that by taking advantage of the so-called passive state of iron, a peculiar property which that metal assumes in certain solu-

tions, that the relative positions of the iron and the copper in the electrochemical series could be reversed and the corrosion of the iron thus prevented. This can be accomplished by using a nitrate solution, sodium nitrate on account of its cheapness and electrical conductivity being the most practical material at hand. In a paper presented at the September meeting of the American Electrochemical Society*, the results of experiments dealing with this passive condition of iron were described.

It was found that upon placing the iron and brass as the anode in a sodium nitrate solution and causing the current to flow toward an iron cathode the zinc and copper could be completely removed, leaving the iron smooth and bright. When a sodium nitrate solution, freshly prepared by dissolving sodium nitrate crystals in water, was used, it was found that it required some minutes for the iron to become passive, but after the solution had been in use for some time, the iron would become passive almost instantly upon placing it as the anode in the solution. A study of this phenomenon revealed the fact that during the passage of the current a small amount of sodium nitrite was produced at the cathode which subsequently diffused throughout the solution, and that it is the presence of this nitrite which aids in the production of the passive state of the iron. It was also noted that after the tanks had been in operation for several days the iron would again lose its passive condition and become corroded almost as readily as if the solution were a chloride or a sulphate. The cause of this was found to be due to a change in the electrolyte, whereby the electrolyte was made quite alkaline with a considerable liberation of ammonia. In keeping the solution in an efficient condition it was therefore necessary that this alkalinity be prevented. This can be done by the occasional addition of a small amount of free nitric acid.

The tanks used for this treatment of bicycle frames, as constructed and installed by the Hanson & VanWinkle Company, are illustrated in the accompanying sketches. Each tank has a capacity suitable for the class of work to be treated therein, the tanks for the front forks being shallower than for the other joints on account of the various forms to be treated. It is desirable to immerse the joints into the solution only far enough to expose the brass, and a few inches should be allowed below the lower part of the anode to allow for the accumulation of sediment. The tanks are usually constructed of carefully selected two-inch pine, and are bolted together to prevent leakage. The method of suspension is considerably different from that used in the ordinary plating tank. The cathodes are placed cross-wise in the tanks and at sufficient distances apart to permit the insertion of a piece of brazed work between them, allowing a distance of one or two inches between the anode and the cathode. The cathode usually consists of sheet iron or steel plates of about No. 14 gauge, which are permanently connected by brazed copper connection to the negative bars of the tank. The anode connections are usually effected by the simple weight of the work upon the strips or bars constituting the positive terminal. When the weight of the work is not sufficient to insure satisfactory contact, an increase in pressure may be produced as shown in the illustration. Each special class of work requires a particular construction of the terminals in order that the work may be handled most economically.

In cases where the entire object must be suspended in the solution, the suspension hooks should be made of iron or steel, copper or other materials being easily corroded by the action of the solution. The electrolyte consists usually of a solution of sodium nitrate of a purity of 98 or 99 per cent dissolved in soft water. One pound of this material to a gallon of water will give a good workable solution. Five degrees B′ is a density usually employed, and the hydrometer serves as a satisfactory indicator for maintaining the solution at its proper density. In using the hydrometer, however, it should be remembered that the indication when the solution contains a large amount of sediment in agitation will be too high and a test should, therefore, be made in a clear solution. The following table gives some data on the solutions of sodium nitrate at different densities.

% $NaNO_3$	s. g.	°B′	resis. pr. c. c.
5	1.0327	5	23 ohms
10	1,0681	9	12.8 "
20	1.1435	18	7.66 "
30	1.2278	31	6.22 "

From this table it will be seen that densities higher than those usually employed will give a solution of lower resistance, but such advantage is not sufficient to warrant the use of a more concentrated solution, which has the disadvantage of not allowing the ready precipitation of the copper and zinc hydroxides which are formed, thus interfering with the proper action of the solution. An economy of material is also effected by using the dilute solutions, inasmuch as when the sediment is removed from the tank only a small amount of the sodium nitrate is wasted.

It is sometimes advisable to add a very small percentage of sodium nitrite to the solution when it is first prepared, as this will insure the immediate desired action of the solution upon the passage of the current. The addition of this, however, is not necessary, for after the tank has been in operation for some time some sodium nitrite is formed at the cathode.

The solution operates most satisfactorily when in a neutral condition. During operation there is a tendency for it to become alkaline, as will be explained later, and this alkalinity is shown by the red litmus paper becoming blue when dipped into it or by the odor of ammonia which may escape if the alkalinity is allowed to proceed to a considerable degree. For satisfactory working, this alkalinity should be neutralized by the occasional addition of nitric acid which should be added in small quantities each day. If the alkalinity be allowed to proceed too far and neutralized by a considerable quantity of nitric acid at any

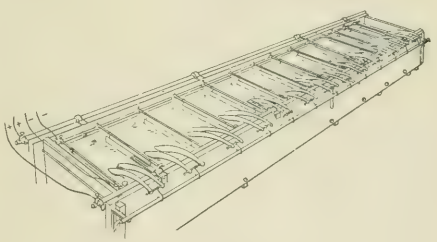


FIG. 2.—TANK SHOWING SPECIAL FITTINGS FOR STRIPPING FRONT FORKS.

one time, it may cause a vigorous evolution of nitrous fumes and this should be avoided so far as possible, as the corrosive fumes are harmful not only to the workmen, but to any metal work exposed to them. By adding the acid in small quantities and properly diluted from day to day, the liberation of nitrous fumes can be entirely prevented.

The proper amount of acid may be determined by the litmus paper test. If the acid be added in a slight excess no damage will be done to the solution, as it merely results in dissolving some of the precipitate, and the presence of such excess of acid is made evident by a deposition of copper upon the iron cathodes.

Some users of this process compound the electrolyte by neutralizing sodium carbonate or sodium hydroxide with nitric acid, but the cost of the solution thus prepared is much greater than when prepared directly from the sodium nitrate crystals. The solution should be comparatively free from sodium chloride or sulphates, and, inasmuch as certain grades of sodium nitrate on the market contain a considerable percentage of these

*Electrochemical Industry, 1903, page 483.

materials, care should be used in obtaining sodium nitrate of a suitable degree of purity. Otherwise, the solution will cause a dangerous corrosion of the iron.

It may be observed that after the solution has been used continually for a number of hours it heats up, and when thus heated the results obtained are not so satisfactory as at lower temperatures. To reduce this heating, either the tanks and the volume of the solution should made larger or the current density decreased. By an examination of the anodes from time to time, it may be determined whether the process is working satisfactorily. This is shown when the brass is removed rapidly, leaving upon the surface a brownish layer which may be rubbed off readily, exposing the bright yellow brass. When there is a thick greenish precipitate adhering to the brass it shows that the solution has become alkaline and the appearance of a brownish precipitate and a brown scum accumulating upon the surface of the electrolyte indicates that the alkalinity has proceeded so far as to cause corrosion and pitting of the iron.

The brass, after it is removed from the anode, is precipitated in the solution as a flocculent greenish-blue precipitate which remains suspended for some time, but gradually settles to the bottom. While the process is in operation, a portion of this material rises to the surface in the form of a scum, and after some experience and observation the appearance of this surface will give an indication of the condition of the solution.

The precipitate may finally accumulate to such a degree as to interfere with the action of the electrolyte, and it is then necessary to remove it. This may be done by drawing off the solution from the bottom of the tank, which carries with it a great deal of precipitate. By allowing this to stand for some time in barrels the clear solution may be drawn from the top and replaced in the tanks. Another method for cleaning out the tanks consists in allowing the solution to settle over night and then siphoning the clear liquid above the sediment. This sediment, which is a mixture of zinc and copper hydroxide changing upon standing to the oxide, represents a waste in the process, for, although it contains metals having considerable value, a method of recovering them cheaply has not yet been worked out.

The current density used in the process may have a value of from five to fifteen amperes per square foot, and with such current densities, and with a solution in the best condition the layer of brass may be removed in from five minutes to forty-five minutes, this depending upon the thickness and uniformity of the coating. If there are lumps of brass of some thickness it may take even longer time to remove it completely, but under such circumstances it is usually more economical to remove these thicker portions by subsequent filing.

The pressure required for this work is between three and five volts, though if the leads from the dynamo are not of sufficient size it may be necessary to have the dynamo pressure of a higher value. Where a considerable amount of work is to be treated in this process, low pressure dynamos of a large current capacity are required. In fact, the introduction of this method of stripping has created a demand for the largest size low-plating dynamos which have been constructed so far. A machine having a compound winding is especially advantageous in this work, as the tanks will operate at the same rate, whether fully loaded or only partially so. Another requirement is that the dynamo should have a sufficient copper brush-bearing surface to prevent excessive heating from the large volume of current required. The conductors leading from the dynamo to the tanks should be of the highest conductivity copper, and of a sufficient size to prevent an excessive drop in them when the tanks are drawing the maximum amount of current. While many plants have conductors of too small a size, it is possible to err on the other side and have conductors which entail unwarranted expense in their installation. A large-sized conductor will allow the use of a lower dynamo pressure, thereby saving energy, but this saving in energy may not be sufficient to counterbalance the greater outlay for copper.

Success in working this process depends upon keeping the solution at the right concentration and chemical composition, removing the articles at the proper time, and applying a suitable current density. The better the brazing has been done, the more satisfactory is the stripping process. If the work is allowed to remain in the tanks too long the current may cause corrosion of some of the brass within the joints, thereby weakening them, but if the joints have been properly fitted and brazed such weakening may be made negligible. A limitation of this process is that brass can be removed only with difficulty from cast iron, such iron not assuming the passive condition, but this is not true of malleable castings, and in wrought iron and steel no trouble from corrosion need be experienced.

After removing the work from the tanks, the pieces are brushed with bristle brushes and water to remove the loosely adhering material, and are then dipped in hot water and allowed to dry in the air, after which no subsequent corrosion will occur unless they are exposed to moisture.

In the manufacture of automobile parts, and in many other instances where iron is subjected to the brazing process this electrolytic stripping method may find useful application.

Silver, copper, tin, zinc, lead, cadmium and their various

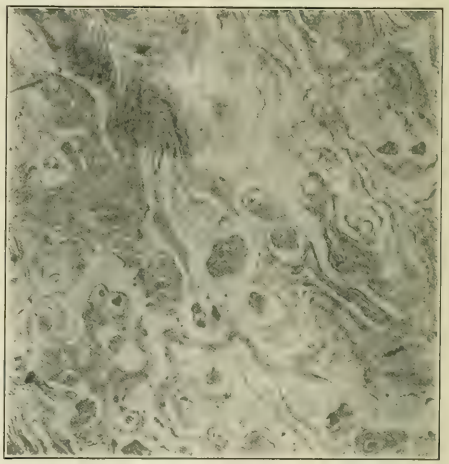


FIG. 3.—SHEET IRON SURFACE FROM WHICH TIN HAS BEEN REMOVED ELECTROLYTICALLY IN A SODIUM NITRATE SOLUTION.

alloys can be removed from iron in this way, and this points out various other applications of the process. It offers a convenient and rapid method for removing silver from plated articles of iron, which are to be resilvered, and also for removing the silver from suspension rods, hooks, and baskets used in silver plating, thus not only recovering the suspension devices themselves, but the silver as well. The silver separates as a sediment in the solution, and by proper heating or chemical treatment may be recovered in useful form. Suspension devices used in copper cyanide solutions may be similarly treated.

Files which have been used upon brass, copper, lead or other soft metal, and have become clogged, may be quickly and effectively cleaned by suspending them as the anode in a sodium nitrate solution.

The layer of tin on tinned iron may be removed completely in a few minutes in the same manner without dissolving any of the iron. This operation may furnish a possible solution of that problem which has received considerable attention of late, the recovery of tin and iron from scrap tin. The question of

commercial success depends, not so much on the completeness with which the two materials may be separated, as upon the handling of the material in such manner that all portions of the surface may make contact with the electrolyte, and so that the current may be utilized efficiently in removing the tin. Fig. 3 is from a photograph of a piece of sheet iron, from which the tin had been removed in about three minutes' time in a sodium nitrate solution, the iron having been so completely cleaned and protected from corrosion that the markings produced by the flow of metal during the process of rolling are clearly defined.

There is a considerable demand for a method of stripping nickel from iron-plated surfaces to succeed the expensive grinding operation, now necessary when an imperfect or worn-out nickel surface is to be replaced, and also for removal of nickel from the suspension rods and baskets. The nitrate solution cannot, however, be used for this purpose as the nickel and cobalt resist the action of the solution in about the same degree as does iron. Yet experiments have shown that while the nickel is not corroded, a thin layer of it may be removed from an iron surface by its long-continued use as the anode through a mechanical separation of the layer of nickel from the underlying iron. This seems to be due to the liberation of the gas within the pores of the metal which forces its way beneath the layer of nickel, thereby effecting the separation.

The chemical reactions which take place in the operation of the process for the removal of brass from iron are as follows: The electrolytic cell consists of a composite anode of copper, iron and zinc; a cathode of iron, copper, or other suitable metal; and an electrolyte of sodium nitrate dissolved in water. The passage of current causes a decomposition of the sodium nitrate into Na, which appears at the cathode, and NO_3, which is attracted to the anode, and at that point unites with the copper and the zinc to form soluble copper nitrate, $Cu(NO_3)_2$, and zinc nitrate, $Zn(NO_3)_2$. The sodium liberated at the cathode unites with the water to form NaOH and H, in accordance with the equation,

$$Na + H_2O = NaOH + H \qquad (1)$$

The hydrogen, instead of being liberated as a gas, acts as a reducing agent on the sodium nitrate, reducing it first to sodium nitrite

$$2H + NaNO_3 = NaNO_2 + H_2O \qquad (2)$$

and then reducing further in accordance with the equation

$$4H + NaNO_3 = NaNO + 2H_2O \qquad (3)$$

and the final reduction may be represented by,

$$NaNO_3 + 8H = NaOH + 2H_2O + NH_3 \quad (4).$$

If the hydrogen were liberated, as it would be in the case of a sulphate, not reducing the sodium nitrate, the action of the cell would be of the utmost simplicity. The soluble copper and zinc nitrates formed at the anode would diffuse and react with the cathode, NaOH precipitating the metals as hydroxides, and re-forming the original sodium nitrate.

By the reactions represented by equations (2), (3) and (4) free alkali and ammonia are liberated and the neutralization requires a certain amount of nitric acid as represented by equation

$$NaOH + NH_3 + 2HNO_3 = NaNO_3 + NH_4NO_3 + H_2O \quad (5).$$

The ammonium nitrate thus produced acts in a manner similar to the sodium nitrate in its dissolving action at the anode, and the process is therefore continuous, provided a suitable amount of nitric acid be added from time to time.

It has been found experimentally that the current when caused to flow at a density not exceeding ten to fifteen amperes per square foot of brass surface, will expend itself almost entirely in removing the brass, and little of the current will be wasted by flowing from the iron. The theoretical rate at which copper will be dissolved is 1.18 grams per ampere-hour, and the rate for zinc is 1.21. The brass, therefore, should be dissolved at a rate of about 1.2 grams per ampere hour, and under practical conditions of working this rate has been realized closely, the efficiency usually being between 75 per cent and 100 per cent. Each ampere hour will, according to the equation (1), liberate .037 grams of hydrogen. From equations (4) and (5) may be determined the amount of nitric acid necessary to neutralize the reducing action of this hydrogen, giving .59 grams of acid per ampere hour. Inasmuch as commercial nitric acid has a content of about 60 per cent HNO_3, the amount of commercial nitric acid required for each ampere hour will be in the neighborhood of one gram.

An interesting experiment illustrating the effect of the passive condition of iron is the following. If a clean iron sheet be dipped in a copper nitrate solution the iron becomes coated with a thin layer of copper by the so-called process of simple immersion. If, however, the iron be connected to a source of pressure, so that it immediately becomes the anode when dipping it into the copper nitrate solution, the deposition of copper upon it is prevented even after the current has been subsequently interrupted. Another method for illustrating the non-activity of the passive state consists in rendering the iron passive by use as the anode in a sodium nitrate solution, and then immersing it for a moment in a copper nitrate solution. If the surface thus wetted be scratched by a knife point, or by contact with a copper wire, the precipitation of copper commences, and spreads almost instantly over the entire surface of the iron plate.

Laboratory of Applied Electrochemistry,
University of Wisconsin.

THE RARE ELEMENTS.

BY VICTOR LENHER, PH. D.

The term "Rare Element" in these days is applied, as a rule, rather loosely, and indeed it is a hard matter to draw a line which will be even approximately logical.

The quantitative distribution of the elements in the crust of the earth from our best and most recent calculations leads us to believe that the element titanium is more plentiful than our common carbon or sulphur, yet to the most of us familiarity with the knowledge of titanium is not to be classed with that of these other two elements, which are not so abundant in nature.

On the other hand, from the view point of the commercial value of the elements, or their compounds, the question of an economical method of extraction or demand and use largely enters as a factor. Not many years ago tellurium was quoted at several hundred dollars a pound, while to-day it can be bought for five dollars or less a pound.

Again, some of the more familiar elements are extremely difficult to obtain in elementary condition, such as, for example, fluorine, and our knowledge of this element has quite recently been much enriched through the work of Moissan.

From what sources the elements which as yet are unknown to us will appear, is largely a matter of conjecture. Whether some of the rare elements of the present day will break down into simpler forms, as has didymium, or whether they will come to us like helium, the atmospheric gas whose spectrum was known in the solar chromosphere before it was discovered on our own planet, can be only speculation. We indeed have to-day the spectrum of elements in the sun of which we have no terrestrial knowledge, and if they ever appear on our own earth it is not likely that they will be plentiful.

When a new element appears its properties and relations are eagerly investigated, usually by a large number of scientists, and its chemistry is subjected to the keenest of criticism. More than the usual amount of interest has centered around the new radioactive elements, one at least of which has had its elementary character fairly well established, and this interest has been brought about not only from the interesting new physical and chemical phenomena they present, but from the observations of experimenters like Ramsay, Soddy, Giesel and Bodlaender that the radiations of radium give off gases whose spectra show the lines of hydrogen and helium, and from the observation by Curie of the elevation of temperature which

radium develops. Of the radioactive elements, radium is the only one which thus far has yielded compounds of a sufficient degree of purity to warrant it being classed as an element. From the chemical side it much resembles barium. It, like polonium and actinium, occurs in pitchblende. Polonium is analogous to bismuth and from the bismuth products with which it appears, it may be obtained by fractionation. Actinium is closely allied to thorium, from which so far it has been impossible to separate it.

Other new radioactive bodies have considerable claims to recognition, and among these mention should be made of the radioactive lead of Giesel, Hoffman and Strauss, and the radiotellurium of Marckwald.

While pitchblende or uraninite has been more largely used as a source of radium, a number of other uranium and thorium minerals also contain these radiferous bodies.

The pitchblende from which most of the radium preparations have been obtained is worked up at the Joachimsthal mine in Bohemia. Many thousand tons of uranium residues are necessary to produce a pound of radium, and thus far only a very small quantity of pure material has been obtained.

In order to extract the radium from pitchblende, the residue from the sulphuric extraction of the ore for uranium is worked up by eliminating the other metals which are present by treatment with a boiling concentrated solution of soda, then with hydrochloric acid. From the hydrochloric acid solution the polonium and actinium are obtained, while the insoluble residue contains the barium and radium as sulphates. The radium is usually separated from the barium by means of the difference in solubility of the chlorides, radium chloride being less soluble than barium chloride.

The Curies use both fractional crystallization from water containing hydrochloric acid and fractional precipitation by alcohol. Giesel separates the radium from the barium by fractional crystallization of the bromides from water.

From the purest radium chloride obtained, radium shows the atomic weight of 225.

The salts of radium, such as the chloride, nitrate, carbonate and sulphate, when freshly prepared resemble the corresponding barium compounds, but they generally become colored. They are all luminous in the dark.

The radiations which emanate from radium are of three kinds. The "*a*" rays, which constitute the major proportion of the rays, produce the greatest portion of the ionization of gases, and they are by far the most energetic of the rays. They are, however, readily absorbed, and a thin sheet of metal will cut off the most of them. The "B" rays are likely longer waves; at all events, they are much more penetrative. They are readily deflected by the magnet. The "X" rays possess the greatest penetrative effect of any, and will excite or produce radioactivity through the air several feet away. They are unaffected by the magnetic field.

The characteristic actions of these various rays can only be touched on here. They cause fluorescent and luminous effects in many instances, such as barium platinocyanide and zinc sulphide. The diamond under the action of radium becomes phosphorescent, and may be readily distinguished from imitations.

The physiological action of the rays are such as to cause blisters similar to a scald. W. J. Hammer states that in a conversation with Professor Curie, the latter said he would not care to trust himself in a room with a kilo of pure radium, as it would doubtless destroy his eyesight and burn all of the skin off his body, and probably kill him.

The new atmospheric gases, *helium, neon, argon, krypton* and *xenon,* are characterized by their great chemical inactivity. No definite compound has been prepared with any of them. Their atomic weights, which are given as He, 4; Ne, 20; A, 40; Kr, 82, and X, 128, have been determined from their densities, the gases being assumed as monatomic. These gases are all present in our atmosphere; neon, krypton and xenon are best obtained by the fractionation of liquid air. Argon is obtained from atmospheric nitrogen by absorbing the nitrogen by means of hot metallic magnesium, or by passing induction sparks through a mixture of air and oxygen over caustic potash when the oxygen and nitrogen unite and combine with the potash, leaving the argon.

Helium, whose presence in the sun was detected by Lockyer in 1868, is found in small quantities in the atmosphere. Its principal sources are certain rare minerals, such as pitchblende, monazite, samarskite and columbite, from which it may be obtained by heating or by treatment with dilute sulphuric acid.

It is interesting to note that a number of mineral springs give off gases which contain more or less of these gases. Recently the gases from certain springs in France and Spain have been carefully examined, and have been found to contain mainly nitrogen along with from 0.9 to 1.8 per cent of argon.

In the alkali group of metals we have *lithium, rubidium* and *caesium.* Lithium is perhaps the most important on account of the use of its salts in medicine. Its most important natural sources are the minerals triphyllite, a triple phosphate of iron, manganese and lithium, zinnwaldite and lepidolite, which are lithia micas, spodumene and other silicates and phosphates. These minerals carry from one to ten per cent of lithia. Nearly 2000 tons of lithium minerals are annually produced in the United States, the New England States, North Carolina, South Dakota and California, producing practically all of the lithia minerals. Over a third of the lithia salts used in the United States are imported.

The crude minerals are valued at about $20 per ton, the valuation being according to the lithia content. The refined salts average a little over $1 per pound. The principle made use of in the extraction of lithia from its minerals is the formation of an insoluble carbonate in strong solution. After fusion and sudden cooling by water, the silicates are pulverized and attacked by hydrochloric acid. The silica is removed by evaporation to dryness, the iron, aluminium, calcium, magnesium, etc., are removed by precipitation with sodium carbonate, after which the clear liquid is evaporated to a strong solution from which more sodium carbonate precipitates lithium carbonate. Inasmuch as lithium forms a very soluble urate, the salts are used extensively in medicine for the removal of uric acid from the system, the carbonate and citrate being used more extensively than the other salts. While lithium imparts a crimson color to the flame, thus far the salts have been little used in the manufacture of firewroks, due largely to the fact that strontium compounds, which also color the flame red, are much cheaper.

Rubidium and caesium in their chemical characteristics much resemble the more common alkali metals, but are much more active. They frequently occur in very small quantities in the minerals which carry the alkalis. While many mineral waters contain these elements in small quantities, the lithium minerals, as a rule, are more important sources. The rare mineral pollux is a hydrous silicate of aluminium and caesium which contains from 13 to 37 per cent of caesium oxide. From pollux, Chabrie extracts caesium by decomposing with hydrofluoric acid, freeing the solution from the heavy metals, treating with ammonium carbonate and evaporating to dryness. The residue, when extracted with boiling alcohol, yields caesium carbonate which is soluble.

Caesium and rubidium are best separated by treating a chloride solution with $SnCl_4$ or $SbCl_5$ when the insoluble caesium double salt is found.

The metals are obtained by heating the hydrates with aluminium, or the carbonates with magnesium. No practical use has thus far been made of these metals or of their compounds.

In the alkaline earths group of metals, *beryllium,* whose chief sources in nature are beryl, chrysoberyl, phenacite, euclase and some more rare silicates, stands between calcium and aluminium, in its general properties very much resembling

both in certain ways. Thus far, neither metallic beryllium or its compounds have had any practical uses; in fact, the methods for the preparation of the metal have hardly received the attention which are warranted by an element which is so like aluminium. The metal can be obtained by reduction of the chloride with sodium at a red heat, or by heating the oxide with magnesium. The specific gravity of the metal is about 2 (its specific gravity varies from 1.64 to 2.1, according to the observer). It does not decompose water, and remains unchanged in the air. It is white and ductile, and can be rolled into sheets. These properties, as given to us, would lead us to believe that its commercial side certainly needs closer investigation. Many of the natural beryllium compounds, as chrysoberyl and the emerald, are valuable as gems, but outside of the uses in scientific investigations beryllium compounds are not in demand. In order to extract beryllium, the minerals are either fused with the alkaline carbonates or with potassium fluoride. In either case the fusion is treated with sulphuric acid. In the alkaline carbonate fusion the silica is volatilized as gaseous silicon fluoride. The aluminium, which is usually present in large amount, is then crystallized out as the potassium alum, after which the beryllium is separated by the addition of the solution to a saturated solution of ammonium carbonate. Beryllium forms a soluble double carbonate with ammonium carbonate, which is decomposed by the addition of hydrochloric acid, after which the hydrate can be precipitated by ammonia and the oxide obtained.

Gallium, indium and *thallium* are of a pronounced metallic character, the first two are very rare, and both occur not infrequently in certain zinc blendes.

The Bensberg zinc blende is the richest source of gallium, and it contains only 16 milligrams of gallium per kilo. The Freiberg blende carries small amounts of indium, from 250 to 1000 milligrams per kilo. A large number of iron ores have been found by Hartley and Rammage to contain gallium and indium. The principle involved in the extraction of gallium is the precipitation of the metal from a neutral solution by means of metallic zinc. Metallic gallium has the very low melting point of 30° C, consequently can be melted in the hand. The characteristic reactions used in the extraction of indium are the precipitation of the metal by means of zinc from a neutral solution and the formation of an insoluble basic sulphite. Neither gallium or indium, or their derivatives, have any commercial use, and thus far have only been of importance scientifically.

Thallium is considerably more plentiful than gallium or indium; it occurs not only in the zinc blendes, but also in iron pyrites, in natural waters, in several of the micas, and in a few very rare minerals which are essentially thallium compounds. One of the principal sources of thallium is flue dust from the manufacture of sulphuric acid. This flue dust is, according to Crookes, leached with boiling water, the chloride precipitated by hydrochloric acid; this chloride is transformed into sulphate by means of concentrated sulphuric acid; the sulphate is purified from other metals by first treating with hydrogen sulphide, then with ammonia. The metal is obtained from the solution either by the electrolysis of the sulphate or by means of metallic zinc. From three tons of flue dust Crookes obtained 68 pounds of impure thallous chloride.

Metallic thallium is very heavy, has a specific gravity of 11.9, oxidizes readily in moist air, forming thallous hydroxide, which is soluble in water, consequently if thallium is partially immersed in water, is allowed to stand exposed to the air, it will slowly dissolve. Two states of oxidation are known with the element, the thallous (Tl_2O) being the most stable. The thallic salts (Tl_2O_3) are quite readily reduced to the thallous. The best method for the precipitation of thallium for analysis is as the yellow insoluble thallous iodide.

Thallium finds considerable use in the manufacture of optical glass. Thallium glass possesses a very high refracting power, more so than lead glass. In addition to the use of the thallium glass for optical purposes, it is also used for the manufacture of artificial gems. Ordinarily thallium can be bought for $10 to $12 per pound.

Germanium, in its chemical characteristics, stands between silicon and the stannic compounds. It is found in a few rare minerals in certain silver ores. The element is quoted by chemical dealers at a very high price per gram, about $70. It has no practical uses at present, but has been of great scientific interest as the element, and the properties of a number of its compounds were prophesied by Mendeleef before its discovery, and the predictions were later fulfilled in a remarkable manner.

Titanium is nowadays considered as one of the common of the elements. Its applications in electrometallurgy by Rossi have attracted wide attention. A recent description of the manufacture of ferro-titanium will be found in this Journal in Nov., 1903. The occurrence of titanium in iron ores and of the oxide in native condition need only be mentioned as abundant sources of this element at this time. The production of the metal by the electric furnace method in a fairly pure condition has been ably demonstrated by Moissan.

The chemical compounds have not yet received the attention that they deserve. We have, however, a few uses developed recently for titanium salts which bid fair to give promising results. Dreher has recommended the dyeing of all kinds of fibre, as well as leather, to deep shades by the uses of titanium salts along with metallic tannates. Titanium potassium oxalate is used along with aluminum acetate, the oxide of titanium being precipitated on the fibre with the dyestuff as a lake.

The trichloride of titanium is a powerful reducing agent: it reduces sulphur dioxide to sulphur, copper sulphate to metal, nitrogroups to amines, etc. The sesquisulphate is also a strong reducing agent; it is obtained electrolytically as a commercial article and comes in the market as a sodium sulphate double salt. It is very likely that the chemical and metallurgical side of titanium will receive far more attention in the next few years than it has in the past, particularly in view of the many promising results which have thus far been obtained.

Department of Chemistry, University of Wisconsin, Madison, Wis.

(To be concluded.)

ELECTRICAL LOSSES IN AN ELECTROLYTIC COPPER REFINERY.

BY CARY T. HUTCHINSON, PH. D.

The article in the December number of ELECTROCHEMICAL INDUSTRY, by Mr. Benjamin Magnus, recalls to the writer a series of investigations made in the winter of 1897 at the same refinery, for it is easily identified as that at Anaconda. A comparison of the results obtained by Mr. Magnus, presumably showing present conditions, and those obtained five years ago, illustrates forcibly how slowly improvements come about in electrolytic copper work. This seems to be due chiefly to what is politely styled "conservatism" on the part of those in charge and to their abnormal foundness for secrecy, in a matter where secrecy is utterly absurd, since there is nothing to conceal.

The following figures were obtained in the course of an investigation covering the cost of producing and using steam power throughout the Anaconda works, and also of determining the cost of electrolytic refining at these works. The energy loss in contacts in the tanks, obviously great, was considered in detail. More than a thousand separate measurements were made with milli-voltmeters, and the results given below are the average of these measurements.

Beginning at the generator terminals, the losses may be divided into, (1) switchboard loss, including all losses from generator terminals to the beginning of the feeders to the tanks; (2) loss in the feeders, including only the loss to the tank mains; (3) loss in the mains on the tanks; each tank, as described by Mr. Magnus, has heavy copper mains, upon which

the anode and cathode bars rest; (4) loss in the various contacts from the end of the feeder to the solution; these losses in contacts include, (a) joint between feeder and tank main; (b) contact between anode bar and main; (c) contact between anode hook and anode bar; (d) contact between anode hook and anode plate; (e) contact between cathode plate and cathode bar; (f) contact between cathode bar and negative main.

Without going into the details of these measurements, the results for one "system," comprising two hundred tanks in series, were as follows:

Currrent			3800 amperes
Pressure at generator			67 volts
Losses:			
(1) In switchboard	0.31 volts	=	0.46 per cent
(2) In feeders	2.00 "	=	3.0 "
(3) In mains	6.00 "	=	9.0 "
(4) In all contacts	7.36 "	=	11.0 "
	15.67 "	=	23.5 "

From these figures, the electrical efficiency from generator terminals to the solution becomes 76.5 per cent, and the total loss from generator to the solution is divided as follows:

(1) In switchboard	2.0 per cent
(2) In feeders	12.8 "
(3) In mains	38.4 "
(4) In contacts	46.8 "
	100.0 "

The loss in tank contacts at 3800 amperes was 7.36 volts, and, therefore, at 4000 amperes, the loss would have been 7.7 volts = 0.0385 volts per tank. The corresponding figures given by Mr. Magnus is 0.0510 volts per tank. Hence, in the last five years there has apparently been an increase of some 35 per cent in the contact resistances, which were, even at that time, excesssive. This drop is unaffected by the number of plates in the tank, as long as the current density is unchanged, which is practically the case.

Deducting the loss in switchboard, feeders and mains, the voltage at the tanks was then 58.7 for 200 tanks = 0.293 volts per tank. It is now given as 0.23 volts per tank. This, of course, is a much needed improvement, and brings this refinery in line with other refineries operating in multiple. It has probably been effected by putting the plates closer together, and, possibly, by some much needed changes in the solution then used.

It is interesting to compute the cost of this loss, and to show the magnitude of the possible economies. For one tank system of 200 tanks, the loss amounts to 60 kilowatts; the cost of the power at that time, not including any charges for depreciation or interest, was $157 per kilowatt, per year of 8,760 hours. This makes the total annual cost of the wasted energy for one tank system $9400, and for the six, $56,400. As the capacity of the refinery was approximately 30,000 tons per annum, this gives a cost of $1.88 per ton for lost energy. While this amount seems small, it is very approximately equal to the interest on the total investment in the refinery plant; hence, a saving of one-half of this loss would justify an increase of 50 per cent in the total investment. As a matter of fact, one-half of this loss can be saved for a very much smaller sum. The increase of 35 per cent, shown by Mr. Magnus' figures, means an added cost of about $10,000 per annum, if the cost of energy is the same as it then was.

A comparison was made at the same time between the operation of this plant and a plant using a series system. The table below gives certain figures of interest, showing the relative cost:

	System. Multiple.	Series.
1. Generator capacity per ton output per day	15.8 kw.	9.0 kw.
2. Floor space required per ton output per day	830 sq. ft.	375 sq. ft.
3. Copper produced per kw.-hour	7.25 lb.	9.6 lb.
4. Time copper is held in tanks	30 days	15 days

It would be a natural supposition that the conditions of operation in an electrolytic refinery are practically uniform; yet one of the most conspicuous facts in the operation of this refinery was the great irregularity in the results. Taking, for instance, as a criterion, the ratio of coal burned to copper produced, the figures for ten successive months were as follows:

	Ratio of Coal Used to Copper Produced.
January	2.09
February	2.17
March	1.82
April	1.61
May	1.46
June	1.98
July	1.01
August	1.22
September	1.04
October	1.25
Average	1.60

Here was shown a variation of more than two to one betweenthe best and poorest performance, with no means of accounting for the difference. This is only a sample of the conditions then existing in the largest copper refinery in the world. It shows what undue secrecy and refusal to compare results with others leads to.

APPARATUS FOR NICKEL AND COPPER ANALYSIS

By David H. Browne.

A convenient device for the use of storage battery and intween the best and poorest performance, with no means of and nickel, is that devised by the Northern Engineering Company of New York. It was desired to use the electric light circuit of 110 volts at night, in connection with a storage battery; with an automatic switch so arranged as to furnish an uninterrupted current. Further, the current was to be so di-

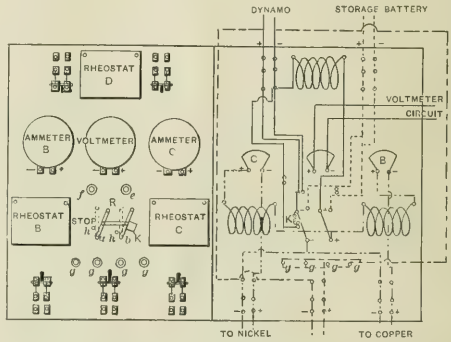


FIG. 1.—SWITCHBOARD, THE LEFT SIDE OF THE DIAGRAM SHOWING THE FRONT, THE RIGHT SIDE THE BACK.

vided as to furnish a steady flow of 0.4 amp. to the nickel plating, and 0.2 amp. to the copper plating frames; together with an independent circuit to an experimental frame, which was to have as strong a current as might be desired.

The panel is 36 in. wide and 46 in. high. The electric lighting circuit enters at the back and passes through the rheostat *D* to the double pole switch *R*, at which point the current

divides. One part passes to the right, enters the rheostat *C*, and flows through the ammeter *C* directly to the nickel plating frames. The current is cut by this rheostat to 0.4 amp., and passes in series through the individual anodes and cathodes on the plating frames and returns on the negative side at the base of the switchboard, through the two-pole switch *R*, and so back to the lighting circuit.

Following the other branch of the positive lead the current passes through the rheostat *B*, where it is cut to 0.2 amp., and passes through the ammeter *B* to the copper plating frames from which it returns on the negative side at the base of the switchboard to the two-pole switch and back to the dynamo.

A branch from the negative side of the lighting circuit

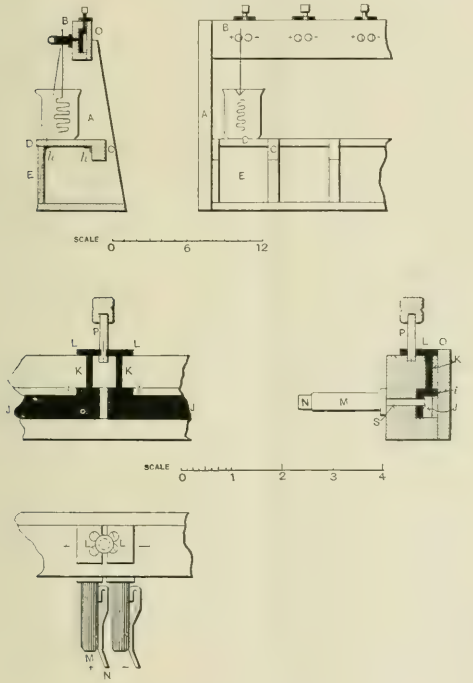


FIG. 2.—PLATING FRAME.

passes around the iron block *K*, forming an electro-magnet which attracts a pole piece secured to the arm *b* of the switch *R*. As long as the electric current passes this magnet holds the arms *a* and *b* in the position shown, and makes all the electrical connections as described.

If the dynamo is shut down the magnet *K* loses its strength, and a spring at the base of the switch *R* comes into play, throwing the switch to the left, as shown by the dotted lines. This cuts out the lighting circuit and throws in a storage battery circuit shown by the dotted wires at the back of the panel. When the dynamo starts again, the magnet overpowers the spring and automatically draws the switch into its original position.

In case any of these instruments should get out of order, an entirely independent lighting circuit is carried to the four lamps, *G, G, G, G*, at the base of the panel, from which a current regulated by the number and size of the lamps can be temporarily connected to either circuit. This can also be used on a separate frame for experimental purposes.

The plating frame consists of a hardwood horizontal piece, *B*, hollowed out at the back to receive the copper conductors *J*. which are covered in by the back piece *O*.

Below and at the back of the frame is a second horizontal strip, *C*, to which are hinged the tables *D*, which are supported by the foot *E*, which is hinged to the table. When a beaker is to be removed from the frame, the foot is pushed back, which allows the table to fall.

The electrical connections consist of a series of short copper bars, to each end of which is soldered an L shaped lug, *i*. Through this lug passes a bolt, *K*, which connects the ends of the copper bars with the cut-out switch *L*. The pin *P*, when placed between the terminals of the switch, cuts out the cathode and anode clamps *M*.

These clamps are of aluminium, and are connected to the copper bars *J* by a screw, *S*. When the pin *P* is taken out, these clamps receive the current which thus passes in series from one plating beaker to the next.

The platinum anodes and cathodes are slipped from the front between the aluminium bar *M* and the brass spring *N*. This holds the electrodes firmly in a notch and avoids cutting the wires by screws, as is the case with the ordinary plating frame.

This apparatus has been in use at the Orford works for nearly two years and has given entire satisfaction.

ELECTRICITY DIRECT FROM CARBON.*

BY PROF. RICHARD LORENZ, PH. D.

By far the greatest part of the energy which is changed into useful work for the various purposes of engineering and human life, comes from the chemical energy of burning carbon. The energy reservoir, given us by nature in the form of carbon deposits, is not inexhaustible. We should, therefore, endeavor to utilize the coal we have to the best advantage. The efficiency of steam engines and gas engines is necessarily small. We now have, no doubt, a number of possible methods for improving the efficiency of the machines; we may refer, in this connection, to the construction of the steam turbine. On the other hand electrochemistry gives us points of view from which a still more perfect utilization of the energy of carbon appears possible. These new points of view are contained in the theory of galvanic cells, and our problem is to design what is commonly called a carbon cell.

We may start with some introductory remarks on the thermodynamics of the subject. From any process which goes on voluntarily in nature, mechanical work may be derived, if we let this process take place in a suitable device ("machine"). The external work becomes a maximum if we succeed in making the process isothermic and reversible at any moment. Under these conditions the process gives the maximum of external work which it is possible to give under any circumstances.

Helmholtz calls that part of the change of the total energy of an isothermic process which can be changed into external work, vis viva, etc., the change of the "free energy" of the system. The difference of the change of total energy, and of the change of free energy is called by him the change of the "bound energy" of the system.

The view of Thomson that the heat of reaction, corresponding to a chemical process, can be changed completely into electrical energy (Thomson's rule), has been found to be not correct since an electrochemical system tends to become warmer or cooler, while its chemical energy is changed into electrical energy, so that if the process is to be isothermic, heat is either to be given off to the surroundings from the cell or to be supplied from the surroundings to the cell.

From the first principle of thermodynamics we get the relation U = A — Q, in which U represents the decrease of total energy, A the work done by the system, and Q the heat supplied from the outside to the system. Each of these quantities may be positive or negative.

*A paper read before the Physical Society of Zuerich. Translated and slightly abstracted from the Mitteilungen of the Society.

From the second principle of thermodynamics we get the relation

$$dA = Q\frac{dT}{T}$$

and by combining these two relations we get the "Gibbs-Helmholtz equation"

$$A = U + T\frac{dA}{dT}$$

The maximum work (A) which an isothermic process can accomplish, equals the decrease of total energy (U) plus the product of the absolute temperature (T) and the temperature coefficient $\left(\frac{dA}{dT}\right)$ of the capacity of the system to do external work.

The great importance of this equation is shown in its application to chemical and electrochemical reactions. The question is whether we can design systems in which the maximum of external work can be obtained. This is really possible if the chemical reactions are used in galvanic cells to generate electrical energy. In this case the external work which appears in form of electrical energy is $e\ n\ F$, where e is the e. m. f., n the chemical valence and F the constant in Faraday's law. $e\ n\ F$ is the free molecular energy of the system. The Gibbs-Helmholtz equation thus assumes the following form[1]:

$$enF = U + \frac{Td(enF)}{dT} \text{ or } e = \frac{U}{nF} + T\frac{de}{dT}$$

To show the application of this formula we give the following examples which prove that Thomson's rule in its original conception is not correct, and which also show that galvanic cells represent systems which, according to their constitution, can transform the chemical energy of exothermic or endothermic reactions, with greater or smaller efficiency, into electrical energy.

As first example, we take the reaction,

$CuSO_4aq + Zn = ZnSO_4aq + Cu + 25{,}055$ calories.

This[2] is a reaction in the Daniell cell Zn, $ZnSO_4$, $CuSO_4$, Cu. According to Thomson's rule we expect electrical energy corresponding to 25,055 calories. In fact, this is in this case nearly correct. We get the e. m. f., corresponding to 25,055 calories, = 1.08 volts, while the real e. m. f. is 1.093 volts, corresponding to 25,263 calories, so that the difference of the two quantities of heat is 207 calories.

The cell has therefore a very small temperature coefficient of e. m. f., and we may consider it to be practically zero, so that in this case Thomson's rule is practically correct.

A second case is.

$2AgCl + Zn + aq = ZnCl_2aq + 2Ag + 26{,}023$ calories.

This is the reaction of the cell Zn, $ZnCl_2aq$, AgCl, Ag.

In this case we get the e. m. f. which would correspond to the heat of reaction ($U/_2 = 26{,}023$ calories) = 1.12 volts. The e. m. f. which the cell really has is e = 1.01 volts, corresponding to 23,453 calories. We therefore get $\frac{Tde}{dT} = -0.11$ volt, corresponding to 23,453 calories. We therefore get $\frac{Tde}{dT} = -0.11$ volt, which corresponds to Q = — 2,570 calories. Since Q means the heat supplied from the surroundings to the cell, we have, in this case, a loss of heat from the cell to the outside. The cell, while working, tends to heat up[3], and if the temperature is to be maintained constant heat is to be given off from the cell to the surroundings. This means that the chemical energy of the reaction is not completely changed into electrical energy, but partly (about 90 per cent) into electrical energy and partly into heat. The efficiency (giving the electrical energy produced in per cents of the chemical energy lost) is therefore 90 per cent. This represents the maximum limit of the efficiency which a cell of this type can have.

A third case is the reaction

$Pb + Cu(CH_3COO)_2 = Pb(CH_3COO)_2 + Cu + 8{,}766$ cal.,

which is the reaction of the cell Cu, $Cu(CH_3COO)_2$, $Pb(CH_3COO)_2$, Pb.

We have in this case $\frac{1}{2}U = 8{,}766$ calories, corresponding to 0.37 volt, while the e. m. f. in reality is e = 0.47 volt, corresponding to A = 10,842 calories.

We therefore have for the difference Q = 2,076 calories and $\frac{Tde}{dT} = +0.10$ volt. In other words, instead of an e. m. f. of 0.37 volt, which we should expect from Thomson's rule, we get in this case an e. m. f. of 0.47 volt, which is more than corresponds to the heat of the chemical reaction. In this case, while the cell works it tends to cool, so that if its temperature is maintained constant, heat must be supplied from the surroundings to the cell. The chemical energy of the reaction in the cell, together with the heat supplied from the surroundings to the cell, are changed into electrical energy, so that we get in this case an efficiency beyond 100 per cent; namely, 123 per cent, if the efficiency is defined as the electrical energy produced in per cents of the chemical energy consumed.

The chemical reactions which we have so far discussed for changing chemical energy into electrical energy were so-called exothermic processes; that is, such chemical reactions which develop heat while they are going on. There are, however, numerous chemical reactions, in which heat is absorbed from the surroundings, and they are called endothermic processes. One of the most interesting results of experimental chemical thermodynamics is the successful proof that it is indeed possible to utilize endothermic chemical processes for performing external work, while, according to Thomson's rule, it should be impossible to obtain any work if the heat of reaction is negative. Nernst and Bugarsky have found, for the first time, such an example, the chemical reaction being

$HCl + KOH = \frac{1}{2}Hg_2O + \frac{1}{2}H_2O + KCl - 3{,}710$ calories.

This[4] is the reaction of the cell Hg, HgCl, KCl, KOH, Hg_2O, Hg.

In this case we have

$U/_2 = -3{,}710$ calories, corresponding to — 0.14 volt, while the e. m. f. is in reality e = + 0.32 volt, corresponding to A = 7,566 calories. Hence, for the difference we get Q = 11,276 calories. In this case, while the reaction goes on at constant temperature, heat is supplied from the surroundings to the system, and this heat is partly used up in supplying the heat of chemical reaction and partly changed into electrical energy[4].

After having thus discussed the thermodynamical foundations of the theory of galvanic cells, we will now take up the problem of getting electricity direct from carbon.

It would be possible to obtain the maximum external work corresponding to the reaction

$$C + O_2 = CO_2 + 97{,}650 \text{ calories}$$

[1] In this equation e is measured in volts, n is the change of chemical valence (a pure number), F is the electric charge of a univalent gram-ion (96,540 coulombs). U is the change of chemical energy, if the chemical symbols in the equation representing the process mean gram-molecules or gramatoms,and is assumed to be measured in joules. If U is given in gramcalories (as is usually the case), its value is to be divided by 0.24, and the above equation assumes the form $e = 0.000\,043\ U/n + T\frac{de}{dT}$. Of course, T is the absolute temperature (or degrees centigrade + 273), for which the cell has the e. m. f. e, while $\frac{de}{dT}$ is the temperature coefficient of the e. m. f.—*Translator.*

[2] 25,055 calories is the heat corresponding to the reaction, if in the above equation each chemical symbol represents one-half grammolecule. Since the change of valence is here two, 25,055 valories represents the quantity U/n in the last equation of footnote 1.—*Translator.*

[3] This is, of course, not Joulean heat, but heat which would appear even if we could design the cell so that the Joulean heat becomes negligible.—*Translator.*

[4] While, from Thomson's rule, one would expect that the above reaction would require the expenditure of 0.14 volt, to be impressed from an external source to the terminals of the cell, in reality the cell acts as battery, and has an e. m. f. of 0.32 volt.—*Translator.*

in form of electrical energy if we could render the burning of carbon in a galvanic cell an isothermic and reversible process. According to Nernst (*Theoretische Chemie*, page 639) we can make calculations which show that the oxidation heat of carbon at ordinary temperature (U = 97,650 calories), may be changed nearly completely into external work. Theoretically we find the maximum amount of external work which we can derive from the reaction as A = 91,470 calories. It also follows that the efficiency of the carbon cell must be the smaller the higher the constant temperature at which it operates. For the e. m. f. at ordinary temperature we get 0.99 volt for the oxidation of C to CO_2, while we have the e. m. f. 1.41 volts at 18° C. for the oxidation of CO to CO_2, and 0.57 volt for the oxidation of C to CO (Bucherer, *Elek. Zeit.*, 1895, pages 502 and 597; Luther, *Zeit. f. Phys. Chemie*, vol. 36, page 385).

These theoretical values appear quite favorable to a carbon monoxide cell, since it gives theoretically a considerable higher e. m. f. than the combination of carbon and oxygen with the formation of carbon dioxide. Of course the former cell, while giving a certain number of ampere hours, consumes twice the quantity of carbon consumed in the latter cell. The former cell would also have some technical advantages, for instance, the easier preparation of pure carbon monoxide gas, while the impurities in carbon or coke would be the cause of many technical difficulties. However, it must be emphasized that the question whether we have to attribute an electromotive force to carbon monoxide, has not yet been definitely settled, although it seems improbable if judged from preliminary experiments.

We may mention that up to the present we cannot say safely that there really exist carbon ions in sufficient concentration, that is, compounds of carbon with electrons. Any electrochemical processes depend on the formation, or the discharge of ions. Hence, the existence of such ions is the fundamental supposition for the validity of the above thermodynamical conclusions for the reason that the reversibility depends electrochemically upon the existence of ions.

It is true, experiments may be made in which carbon appears to show an electrolytic behavior similar to that of metals, for instance, zinc. Such experiments were made especially by A. Coehn. If a carbon anode is used in sulphuric acid of suitable concentration, the carbon goes into solution in form of a brown substance which appears to be similar to the anodic solution of a metal. The solution of carbon even takes place according to Faraday's law. Moreover, from such a solution a deep velvet-black carbon-like coating can be deposited on a platinum cathode, so that we seem to have a reversible process, similar to the case of metals.

These simple experiments, when published, appeared to justify at first sight the hope that it might be possible to dissolve carbon in a similar way as zinc, in a galvanic cell, so that the design of the required isothermic and reversible machine would have become possible. However, such expectations did not realize up to the present, for the following reasons.

First, in carbon electrodes we have never pure carbon, but they consist of hydro-carbons of high complexity. The products of anodic oxidation are mainly benzenehexacarboxylic acid, benzenetetracarboxylic acid, and hexahydrobenzenehexacarboxylic acid, which are substances found in brown coal deposits in combination with Al_2O_3. The first product is mellogen $C_{11}H_3O_4 + 1\frac{1}{2}H_2O$, which by further oxidation is changed into the above substances. (*Zeit. f. Elektrochemie*, vol. 4, page 63.) The black body which is deposited from the solution by electrolysis is not pure carbon, but a substance containing carbon, and also containing O and H. In this case we probably have in the electrolyte a migration of colloids and probably not of carbon ions. The analogy with the solution of metals is thus to be considered as quite limited (Haber, *Grundriss d. Technischen Elektrochemie*, page 182). On the other hand, recent calculations of Bodlaender concerning the solution of carbon have given a very remarkable and interesting result. When carbon is dissolved in aqueous solution we have the reaction

$$C + 2H_2O = CO_2 + 2H_2.$$

This is a process analogous to the solution of zinc with evolution of hydrogen. The calculation shows that the free energy A of this reaction in the case of carbon is negative and equal to 15,230 calories. If we want to dissolve carbon in dilute sulphuric acid, we must consume 0.16 volt. This agrees with the results of the experiments since Coehn found that the solution of carbon in dilute sulphuric acid takes place only under the application of an external e. m. f. The reason is that in this case we must develop hydrogen. If, by means of the solution of carbon we want to get electrical energy, we must use a depolarizer for hydrogen at the positive pole, in form of oxygen from the air, or in form of other oxidizing agents. By using lead peroxide, Coehn really got 1.03 volts with a current of 0.01 ampere. The application of air depolarizers involves various difficulties, which are increased in this case especially by the low speed of the solution of the carbon. If alkali would be used instead of sulphuric acid, the result would be somewhat more favorable.

Anyhow, from these considerations and investigations, it follows that the solution of the problem to get electricity direct from carbon is not theoretically impossible. The practical solution might be found by three different ways.

The first is to design a galvanic cell with carbon as dissolving electrode, hence, corresponding to the zinc in the Daniell cell. In the majority of suggestions of this kind it was proposed to use a carbon electrode in aqueous solution. But since the reaction velocity between carbon and oxygen at low temperature is very small, but somewhat higher at red heat, the use of a galvanic cell with a fused electrolyte seems more promising, although, as mentioned before, the efficiency will be the lower the higher the temperature. The first proposals were cells of the type

Fe, PbO, carbon; Fe, KNO_3, carbon;

but this type of cell is unsuitable, since the oxidizing agent is in direct contact with the anode, so that the carbon is consumed by local action, which does not represent the generation of electrical energy. Researches made in this direction have found a certain conclusion by the construction of the carbon cell of Jacques.

The Jacques cell consists of carbon, fused sodium hydroxide and iron. This proposal of Jacques was announced to the world with considerable advertising skill, yet the extended investigations of Reed, Liebenow and Strasser, Lorenz and Sacher have shown that the original opinion held by the inventor on the action of his cell, is wrong.

In order to demonstrate the Jacques cell, on a small scale, an iron crucible may be used in which sodium hydroxide is being fused. During this time the iron crucible becomes "passive," while at the same time the molten contents assume a brown color. If, now, a bright iron point is put into the fused mass and the iron point and crucible are connected together through a galvanometer, a current is observed which goes from the active iron point to the passive crucible. After a short time this current disappears, because the iron point also becomes passive. If a carbon electrode is suspended in the fused mass and connected with an active iron point through a galvanometer, a current is observed which originally goes from the iron point to the carbon (in the electrolyte). This cell therefore operates, then, at the expense of iron being dissolved. After a short time, however, this current decreases, the galvanometer needle passes through zero and a current of reverse direction is now observed, which, therefore, in the fused mass goes from the carbon to the iron. A current of this latter direction may be obtained from the start if the carbon electrode is connected with the passive crucible through the galvanometer. This current lasts and is produced by the solution of carbon. In this condition the system represents the Jacques carbon cell. (Lorenz, *Zeit. f. Electrochemie*, vol. 9, page 159.)

However, this cell is not a practical solution of the problem

of generating electricity direct from carbon, since the regeneration of the substances formed during discharge is expensive. Moreover, in all carbon cells which use carbon as dissolving electrode only the forms of carbon which are electric conductors, and which are expensive, can be used. Small amounts of impurities greatly influence the action of the cell. For this reason some inventors have used gases like carbon monoxide, illuminating gas, etc., for the design of carbon cells, since they can be obtained in a condition of greater purity. However, such gases contain no longer the whole caloric effect of the carbon.

In order to render such cells active, a gas battery must be constructed with an oxygen cathode and a carbon monoxide anode. Here the question arises whether the carbon monoxide can be electrochemically active since the existence of CO ions has not yet been proven. For the case of a carbonate as electrolyte a depolarizing action of carbon monoxide can be assumed, since it may combine with the CO_3 ions to form CO_2. The suggestion of Bucherer (German patent 88,327) uses this scheme, his cell containing a platinum tube as cathode, through which oxygen is conducted, and a cast iron and nickel tube as anode through which CO is conducted. It seems, however that the action in this cell is different from what the inventor assumes it to be. Borchers (U. S. patent 567,705) has devised a similar cell.

A second method of generating electricity from carbon by an electrochemical device does not intend to produce the maximum work which corresponds to the oxidation of carbon. In this case the energy of the carbon is utilized outside of the cell for regenerating the substances which have undergone a change during the discharge of the cell. Nernst (Bericht über die erste Hauptversammlung der *Deutschen Elektrochemischen Gesellschaft*, page 29) has expressed the opinion that since it is very difficult to transform the chemical energy of carbon directly into electrical energy, it might be possible to arrive at the same result by a roundabout way. For this purpose the energy of carbon is to be transformed into another chemical energy of such a form that it may be immediately utilized in a galvanic cell. To sketch the idea, one might use cells with a zinc anode, and might devise a reversible reaction by which the zinc salt, formed during discharge, is reduced by carbon. Such a cyclic process would also have a maximum efficiency, since all processes which go on would be reversible.

In such a method, however, a loss of free energy is necessarily involved, since the regeneration cannot be rendered absolutely reversible, especially as the salts which have been formed, very often cannot be reduced, or only with great losses.

The Daniell cell might be used in such a method and the zinc sulphate which is formed during discharge might be regenerated by means of carbon to zinc and sulphuric acid, while the deposited copper is rechanged into copper sulphate by means of the sulphuric acid and air. However, the economy of such regenerating processes is so low that it seems not feasible to utilize the energy of the carbon in this way. It might, perhaps, be easier to use for such a purpose the type of cells devised by Lorenz, in which the electrode metals are obtained in form of their hydroxides or oxides; this might seem more promising, because substances are here formed in the cell which are more easily reduced, although it cannot be denied that difficulties of various kind are here present, since irreversible processes probably go on while the cell gives current. Besides, it is questionable whether the practical application of this method would be easy and simple.

A third method of utilizing the energy of carbon is not to try at all to use it electrochemically, but to use it for producing purely caloric effects in combination with galvanic cells. If carbon is used for the simple regeneration of heat, the part of the heat which can be changed into work is limited by the second principle of thermodynamics, so that by this method we cannot transform the total free energy into useful work. Nernst has made the following suggestion. If one should succeed in devising an accumulator which can stand a very high temperature, and which has a considerable temperature coefficient of e. m. f. one might proceed in the following way. The accumulator is heated to a very high temperature, at which its e. m. f. may be relatively small, while it is higher at a low temperature. The cell might, therefore, be charged at high temperature produced by the burning of carbon. If it is then cooled, its e. m. f. increases, and the chemical energy is utilized at ordinary temperature.

For instance, Dolezalek has shown in his investigations on the lead accumulator that two accumulators filled with very dilute acid show a difference of e. m. f. of 0.6 volt, if there is a difference in their temperature of 90° C.

Similar conditions are found in galvanic cells with fused electrolytes which have been investigated by R. Lorenz and his co-workers. For instance, at 857° C. fused lead chloride may be decomposed at a tension of 1.08 volt into molten lead and gaseous chlorine; if the accumulator thus formed is cooled to 506° C. it has an e. m. f. of 1.28 volts. One might, therefore, use two such cells connected one against the other (i. e., lead connected with lead), one being hot, the other cold. Since the latter has a higher e. m. f., the current given out by it may be utilized for charging the hot battery, while the difference of 0.2 volt multiplied by the coulombs represents the heat which is transformed into electrical energy. It is self-evident that there is little hope to realize such cells for practical use, since heat conduction and radiation will cause a loss of energy in a similar way, as in the steam engine, so that the efficiency may be even lower than in the latter. Moreover, the melting point and boiling point of the substances used represent the limits of temperature within which the cell may be operated, so that no great difference of temperature is possible. It is therefore improbable that this scheme may ever find practical application.

To sum up, the carbon cell is theoretically possible and it seems certain that in future new points of view will be found for approaching the solution of the problem. On the other hand, it cannot be denied that, until the problem will be definitely solved, much is yet to be done, and many questions are to be solved which concern the difficulties involved in the internal resistance, polarization, self-discharge, influence of impurities, etc. The importance of the problem has attracted the interest of quite a number of men of science and engineering, and this fact justifies the hope that the thorough study of all questions which are concerned in the problem will lead to its final solution.

FUEL AND HEAT BATTERIES.

By C. J. Reed.

In the newspapers and technical press two batteries representing attempts to get cheaper electrical energy from electrochemical reactions have recently been described, one of which was devised by H. Jone, the other by J. H. Reid. At the request of the editor of Electrochemical Industry, who has sent me descriptions* of these two batteries, I have written the following article.

The two batteries referred to do not appear to differ materially from other batteries which have been tried during the past twenty-five years.

In the Jone battery there is no attempt to get electrical energy from any reaction involving the oxidation of fuel. It is simply a galvanic battery of the ordinary alkaline type, in which metallic tin is substituted for metallic zinc. This is unusual, but not unheard of.

The additional apparatus, in which he conducts heat reactions for the purpose of regenerating exhausted material,

*The Jone battery is described in Electrochemical Industry, 1902, p. 586; the Reid battery in the present issue, p. 30.—Editor.

is no more a part of his battery than a zinc retort or furnace is a part of a gravity battery.

If a small zinc reducing furnace, operated in conjunction with, and as an adjunct to, a gravity battery for regenerating its waste material, would render the battery more economical as a source of energy than the same battery would be with zinc reduced on a large scale in zinc works, then we might reasonably expect a similar result from a tin battery. If such is the case, the evidence of it is not before us in the published description of the Jone battery.

According to this description metallic tin is converted into stannous oxide (SnO) and mercuric oxide (HgO) is reduced to metallic mercury, the reaction being represented

$$Sn + HgO = SnO + Hg$$

The theoretical electrogenic power of this reaction is 1.53 — 0.46 = 1.06 volts, and this is the electromotive force claimed by the inventor, but whether he obtained this electromotive force by calculation or by experiment is not stated. Assuming this to be the observed electromotive force on open circuit (which is all that the chemical reaction could supply), the greatest possible efficiency may be calculated from the other data supplied by Mr. Jone. He states that a cell holding 1.5 gallons of electrolytes gives 23 amperes through an external resistance of .02 ohm. The total resistance of a circuit through which 1.06 volts would produce a current of 23 amperes would be $\frac{1.06}{23}$ = 0.046 ohm. As the external resistance is stated to be 0.02 ohm, the internal resistance must be 0.046 — 0.02 = 0.026 ohm, and the efficiency of the cell as an electric generator could not have exceeded $\frac{0.02}{0.046}$ = 43.5 per cent.

The inventor states that the efficiency is 85 per cent, but the figures he gives shows that it could not have exceeded 43.5 per cent of the chemical energy of the reaction. To this loss of 56.5 per cent must be added the loss of all heat supplied and all energy used in operating the stiring and circulating apparatus and in recovering and regenerating the waste materials.

The effective output of the cell described could not have exceeded 1.06 x 23 x 0.435 = 10.6 watts. Mr. Jone does not state directly the density of the alkaline solution used, but it is reasonable to assume that it was not less than 1.25 sp. gr. This solution would weigh 19 lbs. and occupy 6.8 litres. In order to supply 1 hp-hour, this cell would have to be in operation 70.4 hours and would consume 14½ pounds of HgO and 8 lbs. of Sn, making the weight of the chemicals alone in this 1 hp-hour cell 41½ lbs. The output of the cell would be only 1-70 hp. The space occupied by the cell and furnace would certainly not be less than 3 and probably not less than 5 or 10 times that of the electrolyte, or roughly, from 3 to 5 cubic yards per horse-power of output. The space occupied by the regenerating apparatus described for regenerating nitric acid from nitrous fume, for reducing stannous oxide and for re-oxidizing the mercury, are not included, and this space would be enormous.

The reoxidation of the mercury to HgO by dissolving in nitric acid and driving off the nitric acid by heat is a process which Mr. Jone probably did not actually try, or he would not have recommended it. 1 hp-hour would require not less than 12¼ lbs. of absolute HNO_3 or 17½ lbs. of nitric acid of sp. gr. 1.422.

The recovery of the tin from 9 lbs. of stannous oxide, even according to the admission of Mr. Jone, would require from 1 to 1½ lbs. of coal and according to actual practice from 12 to 16 lbs. The loss of tin in the practical smelting of refined ore or "black tin" generally exceeds 10 per cent, and there is no reason to believe it would be less in the smelting of the stannous oxide residue from Mr. Jone's battery. This loss alone at the present price of tin would, in Mr. Jone's battery, amount to about 20 cents per horse-power-hour.

The recovery of 17½ lbs. of absolute nitric acid as nitrous fumes could be accomplished only by collecting it in many times its weight of water, all of which must be evaporated by heat. This alone would require 10 to 50 times as much coal as that required to produce 1 hp-hour in a steam engine.

Mr. Jone has evidently overlooked the enormous labor of collecting and handling the large quantities of bi-products, as well as the important fact that large mechanical losses are always inevitable in handling, smelting and refining large quantities of expensive materals, such as mercury and tin.

Mr. Jone assumes that his electrolyte of sodium hydrate undergoes no permanent deterioration. This assumption is contrary to all experience in batteries of this type and is not to be admitted.

It appears to the writer that the mere removal of stannous oxide from the cell and its separation from the electrolyte would cost for labor alone more than the coal would cost for producing the same amount of power by steam.

If we were to ignore losses of material altogether and consider only all the losses of energy occurring in the cycle of processes proposed by Mr. Jone, the cost of power would appear to be not less than 50 to 100 pounds of coal per horse-power-hour. A closer estimate cannot be made.

Mr. Jone seems to have realized the enormity of his undertaking and states that he has already discarded the mercuric oxide as a depolarizer and found another which is still a secret. What he may be able to do with this new depolarizer remains for him to demonstrate. We can only judge of what he has published.

The other battery referred to is that described in United States patents 736,016 and 736,017, issued to J. H. Reid. It consists essentially of an iron pot containing fused caustic soda, in which is immersed a porous carbon tube. The tube and iron pot are the electrodes. A current of illuminating gas is supplied to the surface of the electrolyte at its point of contact with the carbon tube.

Jablochkoff, Archereau, Jacques and many others have used the same battery without the fuel gas. Liebenow and Strasser in their experiments on this battery tried illuminating gas and found it did not give as good a result as air.

That the electrical energy of this cell is produced by thermo-electric action at the expense of heat and not by chemical energy has been shown elsewhere,* and may be seen by an inspection of the chemical reactions supposed to take place.

In all electrochemical reactions it must be borne in mind that the substances undergoing oxidation or other electrochemical change must actually transmit (conduct) the current corresponding to that electrochemical change. In terms of the theory of electrolytic dissociation this would be stated by saying that *the ions which change to atoms must do so by giving up electric charges to the electrodes and the atoms which change to ions must do so by receiving electric charges from the electrodes,* that is, by conducting the current.

It follows from this that a non-conducting gas, such as oxygen, hydrogen, marsh gas, and other fuel gases, cannot act as electrodes in a gaseous state. These gases, by merely coming in contact with an electrolyte or an electrode or both, would not become conductors and could not take part in an electrochemical reaction, any more than grains of sand or glass would become conductors by being dropped into an electrolyte. Non-conductors may, by *solution* in a liquid, become conductors and electrolytes. Before we can admit that fuel gases take part in an electrochemical reaction it must be shown that these gases are dissolved as conductors. In the case under consideration there is no evidence of such solution or conductivity.

Let us admit, merely for the purpose of working out a conclusion, that these fuel gases are dissolved and become conductors. The next question to be determined is the electromotive force they could produce in a reaction, and the amount

* See transactions of American Institute of Electrical Engineers, 1898.

of chemical energy which could be converted into electrical energy by their oxidation.

Electrochemical action can take place only by a chemical change in the molecules of an electrolyte through which the current passes in entering or leaving an electrode. If the gases in question are electrochemically oxidized at the anode, the oxygen must come from the electrolyte and must be derived from some oxide in the electrolyte. The only oxides present in the case under consideration are H_2O, Na_2O and Fe_2O_3. The formation heats of these substances are

$$H_2O = 69{,}000$$
$$Na_2O = 155{,}900$$
$$Fe_2O = 197{,}700$$

The formation heat of CH_4 is 20,414; of CO_2, 97,650; of CO, 29,400, and of FeO, 65,700.

The following equations represent the possible reactions which could take place in such a cell, oxidizing hydrogen, marsh gas, and carbon monoxide:

For Hydrogen.

$$2H + H_2O = H_2O + 2H \quad (1).$$
$$2H + Na_2O = H_2O + 2Na \quad (2).$$
$$6H + Fe_2O_3 = 3H_2O + 2Fe \quad (3).$$
$$2H + Fe_2O_3 = H_2O + 2FeO \quad (4).$$

For CH_4.

$$CH_4 + H_2O = CO + 6H \quad (5).$$
$$CH_4 + 2H_2O = CO_2 + 8H \quad (6).$$
$$CH_4 + Na_2O = CO + 2Na + 4H \quad (7).$$
$$CH_4 + 2Na_2O = CO_2 + 4Na + 4H \quad (8).$$
$$CH_4 + 4Na_2O = CO_2 + 8Na + 2H_2O \quad (9).$$
$$CH_4 + Fe_2O_3 = CO + 2Fe + 2H_2O \quad (10).$$
$$CH_4 + 3Fe_2O_3 = CO + 6FeO + 2H_2O \quad (11).$$
$$3CH_4 + 4Fe_2O_3 = 3CO_2 + 8Fe + 6H_2O \quad (12).$$
$$CH_4 + 3Fe_2O_3 = CO + 6FeO + 2H_2O \quad (13).$$

For CO.

$$CO + H_2O = 2H + CO_2 \quad (14).$$
$$CO + Na_2O = 2Na + CO_2 \quad (15).$$
$$3CO + Fe_2O_3 = 2Fe + 3CO_2 \quad (16).$$
$$CO + Fe_2O_3 = 2FeO + CO_2 \quad (17).$$

Of these reactions the first neither evolves nor absorbs energy, the original substances and products of the reaction being identical. All others, except 3, 4, 16 and 17, absorb energy, and consequently could not be sources of electrical energy. The electrogenic power of reaction 3 is only 0.07 volt, and the powers of 4, 16 and 17 are still less. The electromotive force of 0.9 volt per cell, which is claimed for this battery is, therefore, entirely or almost entirely thermo-electric.

THE ELECTRICAL MANUFACTURE OF STEEL.

Process of Gustave Gin.

By P. McN. Bennie.

The following article is an abridged translation of M. Gustave Gin's description of his latest process for the production of steel by electrical means. The principle involved—that of heating a thin stream of metal by the passage of an electric current—is rather novel, and its originality justifies some notice of the process.

This method has been operated, the translator understands, only in an experimental way, thus far, and it therefore remains to be seen whether the calculations of the inventor can be realized in practice. Lacking such actual commercial operation, the translator wishes to disclaim any responsibility for such claims as may be advanced by M. Gin for this process.

It should be noted that the units mentioned are in the metric system, the ton referred to being equivalent to 2204 pounds avoirdupois.

General Considerations.

The changes in physical states and the reciprocal reactions of substances involved in the industrial production of iron and derived metals, require the consumption of a certain amount of energy, hitherto obtained by the combustion of carbon; in the present process an attempt is made to replace this by electrical energy.

The technical solution of this problem may now be considered an accomplished fact; but it is advisable to make certain reservations as regards the economic results. It must not be forgotten, in fact, that while electricity is the most tractable of the forms of energy, it is, generally speaking, also the most costly. It should not, therefore, be employed, except knowingly (with a thorough understanding of the conditions), and its use should be limited to those applications where its superiority is clearly evident. By carefully examining all the data of the problem, it appears certain that the application of electrical energy to the *direct extraction* of iron from its ores, cannot be advantageous, except under certain exceptional conditions.

Besides, it must be recognized that the modern blast furnace, to the perfecting of which so many metallurgists have concentrated their efforts, is a marvellous metallurgical instrument, in which the utilization of heat energy approaches so closely to perfection, that it is seeking Utopia to attempt to substitute for it the electrical furnace. Such a substitution is, furthermore, inconceivable, except in certain localities particularly favored as regards electrical energy and minerals.

But it becomes a different matter when electrical energy is used for the conversion of crude cast iron into steel. In this case the electric furnace clearly has the advantage of the Martin furnace, always providing that the electrical energy may be obtained at an acceptable price, either by the employment of hydraulic power for generating purposes, or by the use

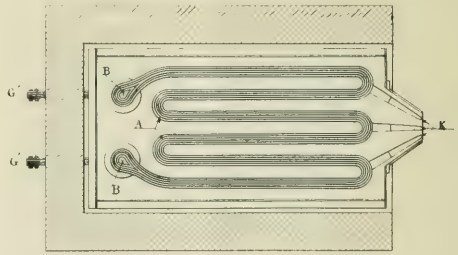


FIG. 1.—GIN STEEL FURNACE.

of the energy available in the waste gases from blast furnaces.

As soon as there is accomplished by the latter means the combination of the blast furnace for cast iron; the Bessemer converter for the common steels; and the electrical refinery for higher grade steels, the industrial metallurgy of iron will have realized an almost perfect utilization of the heat energy of coal.

Gin Process.

From the data submitted by Dr. H. Goldschmidt, of Essen, at the recent Fifth Congress of Applied Chemistry, at Berlin, it appears that the first electrical furnace for the manufacture of steel was proposed by M. Gin, in 1897 (1). Since that time researches upon this interesting question have been continued, and many new types of furnace for steel production have been studied. The latest type depends upon the utilization of the Joule effect, without the use of carbon electrodes.

In the various types of apparatus devised up to the present time, to produce electrothermic reactions in fused cast iron, great difficulties have been experienced in utilizing the energy of the electric current in a bath, the resistivity of which scarcely exceeds 200 microhms per cubic centimeter; generally one is content to produce the Joule effect in a layer of slag

(1) French Patent No. 263,783—February 6, 1897.

floating on the metallic bath, using the notably higher resistivity of this slag.

Besides, the use of carbon electrodes is an obstacle to decarborization, because reduction of the constituents of the slag is effected by the carbon of the electrodes, rather than by the combined or dissolved carbon in the bath.

Finally, furnaces have been devised where the current which passes through the bath is generated by induction, and without the use of any electrodes. But it should be noted that such an apparatus is costly, and involves a considerable magnetic

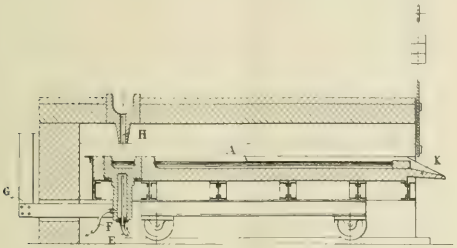


FIG. 2.—GIN STEEL FURNACE.

leakage, incompatible with an efficient utilization of electrical energy.

For the purpose of avoiding these undesirable features, the expedient of the slag bath, and the objectionable use of carbon electrodes, the idea arose of forming the electric furnace as a canal or channel of great length, and small cross section; filling this canal with fused cast iron; and having at its terminals blocks of steel cooled by an internal current of water.

The passage of the proper amount of current in the conductor of fused metal sets free a sufficient quantity of heat to maintain the whole mass in fusion, and to bring it to the most favorable temperature for producing the refining reactions. On the other hand, the large section of the blocks forming the terminals of the circuit prevents a great rise of temperature in them, being aided in this respect by the circulation of cold water.

To give a convenient form to the hearth, the canal in which the metal is held is doubled on itself several times, so that there

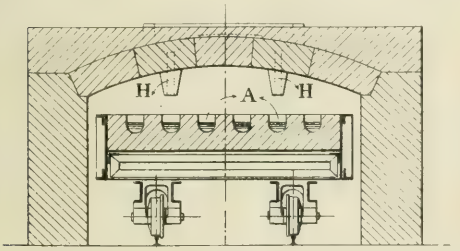


FIG. 3.—GIN STEEL FURNACE.

is formed a sort of huge incandescent lamp, of which the filament consists of a stream of molten iron.

In practice the apparatus would consist of a movable carriage on rails, having a body made of refractory materials. In this carriage body is placed the hearth, containing a channer or canal, having rectangular and semi-circular cross-section (A), and sinuous in a longitudinal sense. The ends of the canal connect with the terminals for the current supply (BB), each of these consisting of a block of steel so shaped as to form an open basin in the canal. The terminal blocks carry a vertical downward extension, which serves for the connection (G), with the conductors carrying the current. These terminal blocks are cooled by an interior circulation of water, which is introduced into the cavity (D) by means of the tube (E), connected with a reservoir by means of a strong rubber tube; the water escapes by the orifice (F), which is also connected by rubber hose to the sewer.

When a charge of metal is to be refined, the crucible carriage is placed in an arched furnace, in order to reduce as much as possible loss of heat by radiation. The furnace being in place, electrical connection is made at (G), and the fused pig-iron is introduced by the funnels (H).

The dilution method (scrap process) may be employed by adding to the iron a calculated proportion of scrap iron, which dissolves in the fused bath. The carbon of the iron diffuses with great rapidity throughout the mass, and the conversion of the whole into steel takes but very little more time than that needed for the fusion of the added metal.

It is also easy to employ the method of oxidation, by the addition of some iron oxide (ore process). The oxygen of the iron oxide added to the bath burns the silicon, manganese and carbon. As in a furnace of this type the temperature can be elevated at will, the carbon is eliminated with great

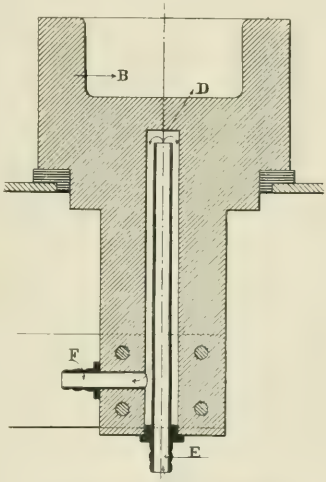


FIG. 4.—GIN STEEL FURNACE.

rapidity, thus obtaining a more complete dissociation of the iron and carbon of the pig iron.

When the pig iron, or mixture of pig iron and scrap, has become well fused, the iron oxide is added by means of a shovel; quite a lively ebullition is produced which lessens gradually. When the process of decarbonization is only manifested by the small blue flames which escape periodically at the surface of the bath, a further quantity of oxide is added. The same phenomenon occurs, but not so strongly marked this time, and the extent of decarbonization is judged by the feebleness of the blue flames.

At this time the test specimens may be taken, and, if necessary, the final additions of spiegel or ferro-manganese may be made, although these latter are not so important in this as in other types of furnaces; this is particularly true with reference to the silicon generally employed to play the rôle of intermolecular combustible, this being quite unnecessary with electrical heating of the metal.

It is interesting to note that in this electric furnace the oxidation of the impurities of the pig iron, and notably that of the carbon, is brought about without the intervention of atmospheric oxygen. Thus the amount of dissolved oxide is reduced, and, consequently, the quantity of deoxidizing ma-

terials to be introduced at the end of the operation is lessened.

It should be remarked that the localization of the heating in the metallic conductor, enables one to obtain temperatures which would not be realizable in furnaces of the Martin type, without melting the arches, and consequent danger of spoiling the metal exposed on the hearth.

The dephosphorizing and desulphurizing materials may be introduced at practically any moment after the metal is well fused; either before, or during, or after the decarbonization. The removal of the slag is effected by means of an iron scraper, which is manipulated by the workmen from the front of the furnace.

The finished metal is poured at the openings (K), which are placed at the front, or end of the furnace opposite the electrical connections.

The method by oxidation (ore process) is dwelt upon at some length, and less has been said about the method by dilution (scrap process) on account of the considerable modifications that would be necessary in the section of the bath, and the necessity which it would entail of varying the voltage of the electric current between wide limits.

The dilution method only possesses real interest in the case of a factory exceptionally placed with reference to a supply of pig iron containing but little sulphur or phosphorus. In fact, it should be kept in mind that dilution without simultaneous oxidation would require the use of very pure materials, because the elimination of impurities would be insignificant.

All the advantages of these two methods may be combined, and their respective inconveniences avoided, by the use of a "mixed method," involving the use of a certain amount of scrap, and oxidation by the addition of iron oxide. It should be noted, moreover, that even in the Martin furnace, the "ore process" is not rigorously followed, but that about one-fifth of the total charge is scrap iron.

The following shows the manner in which it is proposed to operate the Gin furnace in practice:

The pig iron is treated with some iron ore and lime, so as to oxidize the impurities, while producing a basic slag, which facilitates the elimination of the phosphorus. When the purification is sufficient, the scrap iron is introduced into the very hot bath, the slag is removed when fusion is complete, and the final additions of ferro-manganese are made, to reduce the oxide dissolved in the metal.

It is understood, of course, that the use of this mixed process is dependent upon the nature of the possible supply of raw materials; but it is especially adapted for those factories which can obtain at good prices scrap iron, rail ends, bars, sheets, etc., suitable for making proper mixes.

Special Steels.

It is believed that this type of furnace will permit of the easy manufacture of special steels, by the direct incorporation of the additional elements—manganese, nickel, tungsten, vanadium, molybden, etc. Special grades, having a high manganese content, and containing but very little carbon, may be obtained by adding to the bath a suitable proportion of silicon-manganese (which was first prepared by M. Gin, by reduction of rhodonite—French patent No. 316,111), and by oxidizing the silicon by means of manganese dioxide, according to the reaction:

$$mFe + 2nSiMn_2 + 3nMnO_2 = mFe + 5nMn + 2nMnSiO_4$$

Metallic bath — Manganese steel — Slag

It is desirable in this case not to push the temperature of the bath too high, because the manganese is eliminated spontaneously by vaporization.

Furnace Materials.

The materials of which the hearth of the furnace is constructed should obviously be sufficiently refractory to withstand the highest temperatures of the bath. Under this head, lime and magnesia would be preferable, if these bodies were not so easily converted into slag by the silica resulting from the oxidation of the silicon in the bath.

It is true that lime and dolomite play an important part as dephosphorizing and desulphurizing agents, but it is better to employ the calcareous materials mixed with the oxidizing agents. As for silicious linings, they are not sufficiently infusible to be used without rapid deterioration. The best protective coatings are found in rich bauxite, and above all in chromite of iron, which may be agglomerated by ordinary methods.

Example of Application of Process by Oxidation.

For an iron containing:

Carbon	3.60	per cent.
Silicon	1.68	" "
Manganese	1.10	" "
Phosphorus	0.62	" "

The proportions of the above impurities have been chosen arbitrarily to facilitate calculation. The composition of a ton of pig iron may, in fact, be represented by the simple formula here given, expressed in kilogram-molecules:

$$16.6Fe + 3C + 0.6\ Si + 0.2\ Mn + 0.2\ P\ldots$$

If we suppose that the finished steel contains 0.96 per cent carbon, and 0.28 per cent silicon; and if we admit for the simplifiaction of the formulas, that the other impurities are practically eliminated, the ensemble of the reactions may be reduced to the equation:

$$x(16.6Fe + 3C + 0.6Si + 0.2Mn + 0.2P..) + yFe_2O_3 + zCaO$$

Pig iron. — Ore. — Lime.

$$= 17.7Fe + 0.8C + 0.1Si + (3x - 0.8)\ CO$$

One ton of steel. — Carbon monoxide disengaged.

$$+ x(0.5SiO_2 + 0.2MnO + 0.6CaO + 0.6FeO) + 0.1x(P_2O_5 4CaO)$$

Slag.

From this it follows that the production of a ton of steel requires:

Pig iron	919	kilogr.
Fe_2O_3	218	"
CaO	56	"

The quantities eliminated theoretically amount to 57.6 kg., while there is a recovery of 134.8 kg. of iron. We may admit, as practical, the following figures for the production of one ton of steel, by the method of oxidation:

Consumption of pig iron	924 kg.
Iron ores (75 per cent Fe_2O_3)	320 kg.
Lime	56 kg.

Energy Consumed.

The calorific energy derived from the electric current is utilized as follows:

a Heating the metallic bath from 1300° to 1750° C.,
b Heating the reagents to 1600° C.,
c Chemical reactions,
d Radiation losses.

a——Heating the metallic bath:

We raise the temperature of 924 kg. of iron from 1300° to 1750°. But, between these two temperatures the specific heat of the iron varies between 0.40 and 0.58 (which gives 0.48 as mean value). The heat consumed is therefore:

$$q_a = 924 \times 0.48 \times 450 = 199{,}600 \text{ calories.}$$

b——Heating the reagents:

The specific heats (average) of Fe_2O_3 and CaO between 0° and 1600° C. are respectively 0.19 and 0.23, so that the heat consumed in heating the reagents is:

$$q_b = (320 \times 0.19 + 60 \times 0.23) \times 1600 = 119{,}400 \text{ cals.}$$

c——Chemical reactions:

By balancing the heats of formation of the compounds which occur in the two members of the above equation, we have:

$q_c = 75{,}000$ calories.

The total of the calories expended for the heating of the masses, and the chemical reactions is therefore:

$199{,}600 + 119{,}400 + 75{,}000 = 394{,}000$ calories,

which corresponds to a consumption of 456,000 watt hours per ton of steel manufactrued.

d——Radiation losses:

The masonry of the furnace structure being heated by preceding operations, the iron destined for the next operation is introduced at a temperature which does not materially exceed that of the interior of the furnace. The calorific emission of the bath is, therefore, of but minor importance at the beginning, but it increases as an exponential function of the heating of the metal, which is at first very rapid, when nearly all the heat generated by the current is used in heating.

To reduce these losses, when the temperature of the bath reaches 1500° C., it is covered with some of the ore and lime.

At the very first these reagents are heated as much by radiation from the furnace interior as by contact with the bath, of which the radiation is momentarily almost annuled. When the reagents have been converted into slag and fused, radiation occurs at the surface of the liquid slag; later, when the purifying reactions have terminated, the slag is cleaned off, and the surface of the bath being exposed, radiation becomes intense, the temperature finally tending to reach a point where there is a balance between the generated and dissipated heat.

From a few experiments which were made, it has been concluded that the emission of heat from a carefully installed furnace may be expressed provisionally by the following formula, derived from that of Stephan:

(1) $$w = aST^4\theta$$

where

w = the dissipated energy expressed in watt hours,

$a = 3125 \times 10^{-16}$,

S = radiating surface of the bath of steel = lc (l and c being the length and upper surface of the metallic stream),

T = temperature (maximum absolute) = 2000° C.

θ = time in hours.

From the above it follows that

(2) $$w = 5lc\,\theta$$

TOTAL EXPENDITURE OF ENERGY.

For a furnace of power W, producing P kilograms of steel per operation, during θ hours, the calorific expenditure would be equal to

(3) $$W\theta = 450P + 5lc\theta$$

DATA OF CONSTRUCTION AND YIELD OF FURNACES.

The preceding formulæ may be represented under another form. Admitting that the density of the liquid iron equals 7, we have:

(4) $$7lc^2 = 1000\ P$$

or

(5) $$lc^2 = \frac{1000\ P}{7}$$

It may also be noted that at any given moment, we have:

(6) $$W = \frac{E^2}{R} = \frac{E^2c^2}{Pl}$$

In order not to introduce new variables, suppose that the moment of commencing a furnace run is the precise instant chosen for the verification of the preceding equation. At this moment we know approximately the value of $P = 216 \times 10^{-6}$, and we will assume that $E = 15$ volts. We therefore evolve from (6) the following equation:

(7) $$\frac{l}{c^2} = \frac{104 \times 10^4}{W}$$

From the equations (6) and (7) we deduce:

(8) $$l = 122000 \sqrt{\frac{P}{W}}$$

(9) $$C = 0.108 \sqrt[4]{PW}$$

(10) $$lc = 1318 \sqrt{\frac{P^3}{W}}$$

This latter value, substituted in equation (3) gives:

(11) $$W\theta = P\left(456 + 6590\,\theta \sqrt[4]{\frac{1}{PW}}\right)$$

Admitting that a single operation will occupy three hours, the time necessary for the reactions, we may show, by means of equation (11) the following curves, for the values of l, c and P, as a function of W:

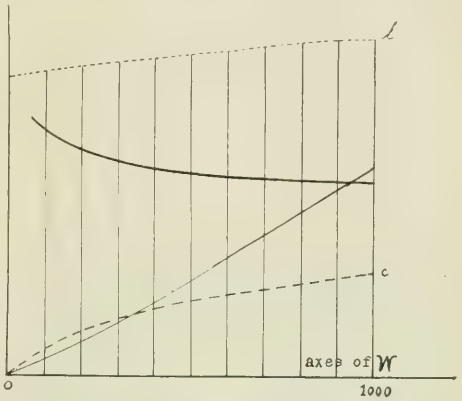


FIG. 5.—CURVE *l* (SCALE 1/100), CURVE *c* (SCALE 1/10), THE THIN, DRAWN OUT CURVE GIVES THE WEIGHT OF METAL PER OPERATION; THE THICKER CURVE THE EXPENDITURE OF ENERGY PER TON

APPLICATION OF THE MIXED PROCESS.

Again taking up the figures of the preceding application (oxidation process), we may write the equation which symbolizes the ensemble of the reactions, thus:

$$x(16.6Fe + 3C + 0.6Si + 0.2P + \ldots) + yFe_2O_3 + zCaO + uFe$$

Pig iron — Ore — Lime — Scrap

$$= (17.7Fe + 0.8C + 0.1Si) + (3x - 0.8)\,CO$$

Finished steel — Carbon monoxide disengaged

$$+ x(0.5SiO_2 + 0.2MnO + 0.6CaO + 0.6FeO + 0.1P_2O_5 + 0.4\,CaO)$$

Slag

Taking, for instance, x as being equal to ⅔, we deduce from the preceeding equation the following proportions as corresponding to the production of one ton of steel:

	Theory.	Practice.
Pig iron	667 kg.,	670 kg.
Fe_2O_3	145.70 kg.,	210 kg. (75 per cent)
Lime	40.90 kg.,	45 kg.
Scrap	267.68 kg.,	285 kg.

Consumption of energy:

a——Heating bath of pig iron,

$q_a = 670 \times 0.48 \times 450 = 144{,}700$ calories,

b——Heating the reagents,

$q = (210 \times 0.19 + 45 \times 0.23) \times 1600 = 80{,}400$ cals.

c——Chemical reactions,

$q = 48{,}900$ calories.

d——Fusion and heating of the iron,

$q_d = 285\ (410 + 0.48 \times 240) = 149{,}700$ calories.

c——Radiation losses.

$q_c = 5\ lc\theta$ watt hours

For a furnace of W kilowatts, producing P kilograms of steel for each run of θ hours, we have:

$$W\theta = 480P + 5\ lc\theta \tag{12}$$

By taking the same calculations as the preceding case we have:

$$l = 12200\ \sqrt[4]{\frac{P}{W}} \tag{13}$$

$$c = 0.53\ \sqrt[4]{PW} \tag{14}$$

$$lc = 1803\ \sqrt[4]{\frac{P^3}{W}} \tag{15}$$

$$W\theta = 480\,P + 9315\ \sqrt[4]{\frac{P^3}{W}} \tag{16}$$

By taking the value of $\theta = 3$, the equation may now be written:

$$W = P\left(160 + 9315\ \sqrt[4]{\frac{1}{PW}}\right) \tag{17}$$

From these equations we may construct the following curves:

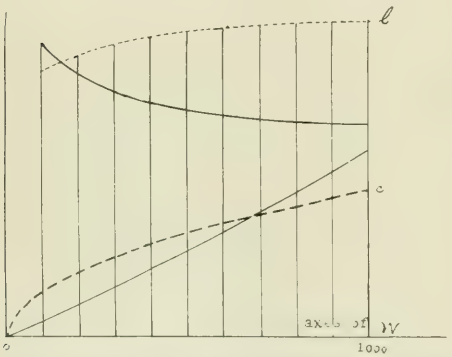


FIG. 6.—THE DOTTED CURVES REPRESENT l AND c. THE THIN, DRAWN-OUT CURVE THE WEIGHT OF METAL PER OPERATION; THE THICK CURVE THE EXPENDITURE OF ENERGY PER TON.

Cost of Production of Electric Steel.

In order to determine the cost of production of the steel, we will suppose that the electrical furnaces receive the pig iron direct from the blast furnace. These calculations have been based upon an annual production of 30,000 tons of 2204 pounds each:

	Ore process.	Mixed process.
Pig iron	925 kg.	670 kg.
Scrap iron		285 kg.
Iron ore (75 per cent)	320 kg.	210 kg.
Lime	50 kg.	45 kg.

Following the preceding calculations, and supposing electric furnaces of 650 kw., there would be expended:

	Ore Process	Mixed Process.
Electric furnaces (30,000 tons)	16,200,000 kw-h	18,000,000 kw-h
Machinery and appliances	2,640,000 kw-h	2,400,000 kw-h
Total	18,840,000 kw-h	20,400,000 kw-h
For 8000 hours absolute per annum	2,355 kw	2,550 kw
Or, allowing for losses and hindrances of all kinds	2,400 kw	3,709 kw

(Note): Here follows a series of calculations showing the cost of materials, labor, operation, etc., which, being based upon French prices, would not give an accurate idea of cost for America. As a result, it is claimed that steel can be produced from pig iron at about 83 francs (about $16.60) per ton of 2204 pounds avoirdupois.—*Translator.*

Conclusions.

In order to avoid the accusation of undue optimism, the preceding estimates, it is claimed, have been based upon prices sufficiently high, and the electrical energy can easily be had at the price calculated ($16.00 per kilowatt year). (This is quite true in France.—*Translator.*)

A combination of conditions more favorable would reduce still further the cost of production. It is not difficult to imagine a company having minerals at $2.60 per ton, and proprietor of hydraulic power. Under such circumstances the electrical energy would be available at $8.00 per year per kilowatt, which would still further reduce the cost per ton of finished steel.

The translator desires to add that some water powers can be rented at as low as $8.00 per kilowatt year; such powers would supply current up to 5,000 kw. at least.

The idea certainly contains some food for reflection, and, as pointed out by the translator in a previous article,* would warrant careful study upon the part of our American blast furnace operators.

EXTRACTING GOLD AND SILVER AT WALLSTREET MILLS, COLORADO.

By Frank C. Perkins.

An electro chlorination process has recently been developed by Mr. John E. Greenawalt, and is now in continuous operation at Wallstreet, Col., in the mill of the Nancy G. M. & T. Co. The accompanying illustration Fig. 1, is an exterior view of this mill, which is located about a third of a mile from the mine. The ore is first crushed and is sampled, one ton in twenty, being taken to the sampling room automatically, as the ore leaves the crusher and passes to the elevator, which carries it to the ore bins and dryers. After it has been completely dried, it is automatically fed to several sets of Davis rolls, which thoroughly pulverize the ore. It then passes to another large ore bin, and is ready for the furnace. The ore is conveyed to the roasting furnace, which is heated by means of

FIG. 1. WALLSTREET MILL, COLORADO.

two Greenawalt gas producers, utilizing bituminous coal. On leaving the roasting furnace the ore drops into a furnace pit, where salt is added to chlorinize the silver, and some of the baser metals, which would consume chlorine in the vats, were the salt not added. The accompanying illustration, Fig. 2, shows the large leaching vats, to which the ore is conveyed

* Electrochemical Industry, 1902, p. 165.

after it leaves the furnace pit, and Fig. 3 shows the arrangement of the regenerating cells, in which the chloride and bromide solution is converted into an active gold solvent. The illustration, Fig. 4, shows the precipitating tanks where the metals are precipitated by the action of the electric current, the gold and silver being deposited from the solution.

THE CRUSHER AND SAMPLER

The Wallstreet mill is equipped with a 10 x 24 Blake rock

FIG 2 LEACHING VATS

crusher, and, as above mentioned, the ore is automatically sampled as it passes to two large ore bins and dryers. The ore is very refractory, containing telluride and sulphide minerals, with an average of about 8 per cent sulphur. The ore conveyed to the sampling room is rolled to 3-inch mesh, and again sampled and ground.

DRYERS AND ORE BINS.

The dryers, as well as the ore bins, are of special construction, and are of more than passing interest. There is an outer cylinder bin 40 feet high, and 12 feet in diameter, constructed of sheet steel, and another inner steel shell also of cylindrical shape, with its top covered. The inner shell is 15 feet high, and 7 feet in diameter, and this leaves a space of about 2½ feet for the ore between the two cylinders. There are a large number of 1-inch holes in the inner as well as the outer cylinders, and the waste gases from the boilers are forced through these holes in the inner cylinder, finally passing

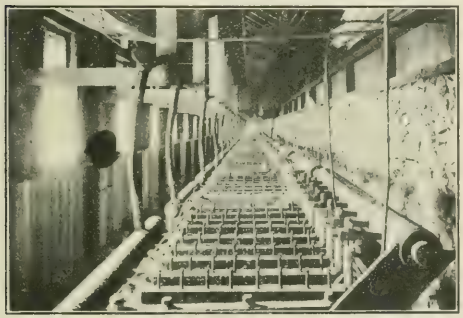


FIG 3. REGENERATING CELLS

through the two or three feet of ore. The heat from these waste gases dries the ore thoroughly, when it is ready for the rolls.

THE PULVERIZING ROLLS.

The mill is equipped with several sets of 16 x 42-inch Davis pulverizing rolls, and the ore is automatically taken from the bins above mentioned, and fed in even and constant streams through the rolls, which pulverize it to a 12 mesh. It will be noted that the ore, in being dried by the waste gases, saves a heavy expense for fuel and labor. The storage bins, which hold the ore as it passes to the rolls, have each a capacity of 500,000 pounds, or a total of several hundred tons. The roll room is also equipped with Jeffrey inclined vibrating screens, and continuous bucket elevators operated at slow speed. The ore, after being pulverized in the roll room, passes to another large ore bin, with a capacity of 1,000,000 pounds of crushed ore, which is ready for the roasting furnace.

THE ROASTING FURNACE AND GAS PRODUCERS

The ore is fed to the furnace in an interesting manner, adjustable gates being provided at the front of the ore bin, and the ore rushes out through the openings of these gates, while rabble plows cut into and plow the ore to the hearth of the furnace. It will be readily seen that the amount of ore which is fed to the furnace can easily be controlled by lowering or raising the bin gates above referred to. The two gas producers designed by John E. Greenawalt, use pea coal, which is converted into ashes and producer gas. These gas producers have fuel beds, somewhat less than 4 feet in depth, supported on a water-sealed bed of ashes. The coal is fed to the gasifying zone continuously and automatically, while the steam and air passes through the white-hot fuel bed, thus forming the producer gas. The gas burns between the ore bed and the arch, and the flame of gas can be thrown throughout the entire length of the roasting furnace. This furnace has a straight

FIG 4 PRECIPITATING TANKS

line reverberatory with a roasting hearth 120 feet in lenght, and somewhat less than 12 feet in width. There is an endless chain at each side of the furnace, to which the ends of the rabbles are attached. The endless chains pass over sprocket wheels at one end of the furnace, and over sheave wheels at the other end. Ball bearings are provided for the rabble wheels, which run on a hollow cast-iron track on each side of the furnace, which is kept cool by a water pipe passing through it. This furnace has been found to give excellent satisfaction, with little or no trouble in connection with the passing of the rabble and chains directly through the furnace.

THE FURNACE PIT.

The furnace pit is capable of holding 300,000 pounds of red-hot roasted ore, which drops into the pit as it passes through the furnace. The pit is 12 feet in diameter, and, as mentioned above, a small amount of salt is added as the ore falls into this pit. The ore is continually withdrawn from the lower portion of the pit, and the ore is cooled as it nears the bottom, where it is taken out, the red-hot ore, of course, being at the top, cooling and digesting in its own heat, on the way down for about twenty-four hours, when it is ready to be conveyed to the large leaching vats.

THE LEACHING VATS

The leaching vats are constructed of wood, as shown in Fig. 2, and are about 5 feet deep, and 30 feet in diameter. At

the bottom of the vats, sand is used as a filter, and they are constructed similar to leaching plants for cyanide solutions. The solution employed in these leaching vats is a strong brine, the solution of common salt being about 15 per cent. The solution also contains bromine, about ⅛ per cent, in the form of a bromide.

The Regenerating Cells.

The regenerating cells consist of a series of two compartments, the cathode department and the anode compartment, the two being separated by means of an asbestos mill board porous diaphragm. Two perforated wooden boards on each side of this asbestos diaphragm are used to support it and hold it in position. A series of graphitized carbon plates are used as anodes, these carbon plates measuring ⅝ x 20 x 4. A sheet of perforated lead is used as cathode. The solution, as it passes through the regenerating cells from the leaching vats and precipitating cells, is charged with free bromine and chlorine, and compounds of these two elements, by the action of the electric current. Thus the chloride and bromide solution is converted into an active solvent of gold, and it dissolves the gold and silver as it percolates through the ore into large vats, and then passes through a series of precipitating tanks, where the metals are deposited by the action of the electric current. The solution passes again through the regenerating cells, where it is again charged with chlorine, and again passes through the ore. In this way the solution is used over and over again continuously. In the regenerating cells in passing through the solution, the current electrolyzes the sodium chloride, and this takes place with the evolution of hydrogen and formation of sodium hydroxide at the cathode, while chlorine gas and compounds are produced at the carbon anode and are absorbed by the solution until it is thoroughly saturated; then bromine or chlorine gas is released. This gas is collected and brought into contact with the ore, which is in the furnace pit.

In the regenerating cells the current density is about 20 amperes per square foot, a current of about 400 amperes being received by each cell, the potential being about 4¼ volts. Mr. Greenawalt states that 12 of these cells are sufficient to treat 200,000 pounds of ore, when the latter is free from alkaline compounds or lime, and is thoroughly roasted. He states that the object sought is to saturate the solution around the carbon plates with chlorine, and then pass it to the ore. The solution is thus made a medium of transporting chlorine to the ore mass.

The Precipitating Cells.

The cells in the precipitating room, seen in Fig. 4, are filled with lead plates, arranged about 1½ inches apart, one-half of the plates being connected with the negative conductor, and one-half to the positive. The solution passes around these plates in a zigzag path, the gold and silver being deposited upon the cathode plates. This deposit is in the form of a slimy black powder, a large proportion of it dropping to the bottom of the tank. In the precipitating cells the current density is 1/36 ampere per square foot. Mr. Greenawalt states that by extracting the silver with the gold it is possible to treat gold-silver ores to a much higher percentage than by other methods. In order to extract the silver, chloride of silver must be formed in the furnace pit and the strong solution dissolves this silver chloride, the free chlorine acting upon the gold contents of the ore. The Greenawalt electro-chlorination process is being introduced by the Wallstreet Gold Extraction Co., of Wallstreet, Boulder County, Col.

SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.

Industrial Electrochemistry.

Electrolytic Refining of Gold.—With reference to the paper of Tuttle, published in Electrochemical Industry, 1903, page 157, on the Wohlwill process used in the Philadelphia mint for the electrolytic refining of gold, the inventor of the process, Wohlwill, makes some remarks in *Zeit. f. Elektrochemie*, October 29. In the Philadelphia mint no bullion is treated which has a fineness less than 0.940 gold, so that it contains never more than 5 per cent of silver. The present author states that this is not necessarily a supposition for the application of his process, but is rather due to the fact that in Philadelphia a temperature of 50° to 55° C. is used, which is 15° to 20° below what he considers to be the normal temperature for his process. This relatively low temperature is said to have considerable influence, not only on the properties of the deposited gold, but also on the solution of the anode. The cathodic gold deposit obtained in Philadelphia is soft, and under slight pressure it may be formed in a die press, while the gold deposited at the higher normal temperature is compact and coherent and cannot be formed by slight pressure. On the other hand, at the normal temperature a larger anodic current density may be used than with the temperature 10° or 15° lower, without developing chlorine at the anode. The use of a lower temperature requires, therefore, a lower current density. If the normal temperature is used and no special haste is necessary, even the most impure Klondike gold, containing 21.9 per cent of silver, may be refined by the Wohlwill process. If one wants, however, to refine the main part of the gold in twenty-four hours, the contents of silver should not be more than 15 per cent, even at the normal temperature. Alloys with a content of silver of approximately this amount are continually refined in Hamburg. If the content of silver is 8 or more per cent, it is necessary to scrape off, from time to time, the layer of silver chloride formed on the anode.

Treatment of Slimes by Cyaniding and Electrical Precipitation on a Mercury Cathode.—In a paper by Mumford, published in the *Transactions Australas. Inst. Min. Eng.*, 1903, 9, page 96, and abstracted in the *Journal of the Society of Chemical Industry*, September 15, the advantages for the electrolytic precipitation of gold on a mercury cathode are summed up as follows. Extraction and precipitation may be effected without filtration; the solution need not be clear for precipitation; the precipitation is equally good, whether from strong or very weak cyanide solutions; the presence of copper salts is not detrimental; the gold is recovered as an amalgam, which only requires retorting and melting; amalgamation of slimes beforehand is unnecessary, as any coarse gold present is amalgamated during precipitation. The essential features of a mercury cathode are thus summarized: The surface of the mercury should be as large as possible, and be kept in perfect condition by some simple means; the minimum quantity of mercury should be used; and the right current density should be employed. Some information is given on the Riecken process and the Mumford process. The Riecken process has been employed at the South Kalgurli mine since December, 1900, about 3,000 tons per month being now treated. In this process an iron vat is used with vertical ends, 11 feet high, by 8 feet wide, with inclined sides 13 feet long, and rounded bottom. It holds 17 tons of ore. Paddles mounted on a horizontal shaft passing through stuffing boxes at the ends are rotated at 12 revolutions per minute. The sides and bottom form the cathode, and are lined with amalgamated copper, over which mercury is kept flowing, being drawn off below and elevated by compressed air to the top of the vat. Iron bars, 3 inches by

1 inch, suspended about 18 inches from the bottom, serve as anodes. The discharge valve for the pulp is placed 4 inches from the bottom, and the mercury remains in the vat during the discharging period. About 400 to 500 pounds of mercury are required for one vat.

MUMFORD'S electro-cylinder consists of a steel plate cylinder, lined with amalgamated copper, and with wooden ends; it is supported on rollers and rotated at 5 revolutions per minute. The anodes are 2-inch round iron bars, supported from end to end of the cylinder, and making electrical contact by means of brushes outside the cylinder at one end. Wooden bars to assist the agitation are similarly supported. A 6-inch valve, with an elbow, is placed at one end, 3 inches from the bottom, for use as a discharge in that position, or as an inlet when the cylinder is turned through a half revolution. A spring valve for the escape of gases is also provided, opened automatically by a tappet, when it is at its highest point. A locked mercury cock is placed in the periphery of the cylinder. In use, mercury is charged in until it is ½ inch deep on the bottom, and the cylinder is filled with charge within a few inches of the top. The whole is then rotated on its horizontal axis at 5 revolutions per minute, and current is supplied at a density of 0.5 amperes per square foot of the amalgamated copper cathode surface. The latter is kept clean by its frequent plunge beneath the mercury bath. Most of the amalgam passes into the mercury, and can thus be run off at the "clean-up." Amalgam adhering to the copper is removed by returning the cleaned mercury and agitating it with sand, if necessary, after softening the amalgam by means of steam. A cylinder 20 feet long and 5 feet in diameter holds 16 tons of pulp (equal weights of solution and ore), and requires about 300 pounds of mercury and 150 amperes. A slime assaying 6 dwts. of gold would require about eight hours for complete precipitation, or one assaying 1 to 2 ounces about 12 to 16 hours. Prior to use, battery tailings would be classified to separate sand, and the slimes would be thickened to the right consistency in spitzkasten; they would then be transferred to agitation vats and mixed with cyanide. By modifications described the process is applicable to sulpho-telluride ores. The current density to be employed depends largely upon the condition of the surface of the mercury. When the cylinder was maintained in rotation a current density of 0.8 ampere per square foot could be used as a maximum, but any higher density led to a partial surface-deposit of gold, which did not amalgamate, and which was mechanically retained in the pulp. At 2 amperes per square foot, none of the deposited gold amalgamated, but all was lost. Rose has fixed 0.01 ampere per square foot as the maximum for simultaneous precipitation and amalgamation, this low figure being probably accounted for by the difficulty of keeping the mercury surface in good order. With weak solutions it was found that the weight of gold deposited was not in proportion to the current density, and a current density of 0.5 ampere was practically as good as one of 0.8 ampere per square foot. The potential difference may be from 3 to 5 volts. It is recommended to add salt if fresh water be used.

Electric Smelting of Copper.—In a paper, published in the *Mémoires de la Société des Ingenieurs Civils de France* and abstracted in *Engin. Mag.*, November, VATTIER gives an account of tests made at Grenoble with the Keller and Leleux furnace for the electric smelting of copper. The tests were made with samples of Chilean copper ore and 8,000 kg. of ore were treated in the electric furnace and fully reduced to a matte in eight hours by the expenditure of 500 kw. The ore contained about 7 per cent of metallic copper, and the resulting matte showed 43 per cent of metallic copper, while 0.1 per cent of copper was found in the slag. The consumption of the carbon electrodes during the operation amounted to 6 to 7 kg. per ton of ore treated, but by the use of artificial graphite electrodes this consumption may be reduced to 5 kg. per ton. The furnace used is of the double type, there being an upper crucible in which the ore is fused in the arc formed between two electrodes, and a lower portion into which the fused material flows, the latter being provided with movable carbon electrodes, which may be plunged into the molten bath, or raised above the surface. By this arrangement the fusion is effected in the first crucible, and the reduction in the second one, the latter operation being capable of close regulation, the slag being drawn off above, and the fused matte by separate openings lower down. The author concludes that in Chile, where fuel is expensive, and water-power available, this process would be a commercial success.

Electrodeposition of Copper.—COWPER-COLES, who has had a long and extended practical experience in the electrodeposition of metals, publishes an article in the December number of the *Electrochemist and Met.*, giving brief illustrated descriptions of a great many processes. He first discusses the plating of iron with copper. The iron surface is freed from scale, oxide and grease by any of the well-known methods, such as sand blasting and pickling, and is then copper plated in an alkaline copper electrolyte which is mostly the double salt of cyanide of potassium and copper. While a considerably higher voltage is required for depositing copper from an alkaline electrolyte than from an acid electrolyte, yet the latter is unsuitable, because iron, when placed in an acid copper electrolyte, is coated with copper by chemical interchange, and the coating is not adherent, and can easily be removed. The electrodeposition of copper upon iron is a large industry. Copper is electrodeposited upon iron hydraulic rams, barrels of guns, tubes, chains, wire, iron sheets for roofing purposes, springs, lamp-posts, ornamental columns, statuary, bridge links, electric light carbons, zinc plates for roofing purposes, wood and other non-metallic substances. Ropper's, Marino's, Crane's and Sneider's methods for coppering ships' bottoms are briefly described. It is mentioned that ships with copper bottoms have been the cause of more than one legal action, due to damage done in shipping when lying in port. A typical case occurred at the port of Leghorn, when an action was brought against owners of copper bottoms lying in the basin of the harbors. The ships and iron vessels lying in the harbor were found to be materially damaged by the galvanic currents set up from the copper bottoms of the wooden yachts, electrical connections being made with the steel vessels through the ropes and hawsers which were used to fasten them to the different buoys. Damage to the steel and iron ships was clearly proven, and the copper bottomed yachts had to be removed from the harbor. A great many different processes are briefly noticed, for instance, copper plating on wood, electrodeposition of copper around glass prisms, copper plating of barrels of guns, steel wire, etc. The difficulty experienced with the steel-cored, copper-coated wire is the rapid corrosion of the steel if the copper is penetrated. The use of copper casings for railway carriages, and the copper plating of printers' rollers is also discussed. The author then gives quite a number of solutions. Roseleur's electrolyte is commonly used, as it may be worked at any temperature. It is prepared by working off 3¼ avoirdupois ounces (92 milligrams) of copper acetate into a thick paste, with a little water; then an equal weight of sodium carbonate crystals is added, with about 1½ pints (0.85 liter of water, and the whole is well stirred for a few minutes. An exchange thus takes place between the sodium carbonate and the copper acetate, with the result that the water contains copper carbonate in suspension, and a sodium acetate in solution. Three and one-quarter ounces of sodium bisulphite are now added in a second 1½ pints of water, and, finally, five pints (2.84 liters) of water, containing 3¼ ounces of potassium cyanide, are introduced. The pale yellow-colored precipitate produced on the addition of the bisulphite will be gradually dissolved on stirring with the cyanide, and should completely disappear after a few minutes, leaving a practically colorless solution. Should it not be so, a little more of the potassium cyanide must be added by degrees, until the decolorization is

perfect. If necessary the bath should be finally filtered. When the bath is used hot, say at 65° C., or 149° F., the quantity of copper may be increased and a stronger current may be used. Pfanhauser has modified this solution. His bath, which gives an excellent coating of copper on iron and zinc, is made up with sodium bisulphite and carbonate, copper potassium cyanide and potassium cyanide, the first two named salts being mixed in advance, with formation of CO_2 and Na_2SO_3. The following bath was found to give good results: Na_2SO_3 (Calc.), 20 grams (.308640 grams); $NaHSO_3$, 6 grams (.092938 grains); Na_2SO_4 (calc.) 20 grams; $Cu(CN)_2KCN$, 30 grams (462.969 grains); KCN, 2 grams (30.8646 grains) per liter (1.7608 pints). The current density should be 0.003 to 0.004 amperes per square cm. (2.8 to 3.7 per square foot), and the pressure between the electrodes, which are 15 cms. (5.9 inches) apart, is 2 to 2.5 volts. Some other solutions are also briefly mentioned. The article is concluded by some notes on the coating of arc lamp carbons, with copper to insure a good metallic contact with the carbon holder, and the coating of zinc with copper. If the solution is used exclusively for plating zinc with copper, the following electrolyte is recommended by Roseleur: Water, 10 quarts (11.36 liters); tartar free, 6.7 ounces (190 milligrams); crystallized carbonate of soda, 15 ounces (425 milligrams); blue vitriol, 6.7 ounces (190 milligrams); caustic lye of 16° Be., ¾ pound (340 milligrams). The solution is prepared by dissolving the tartar and the crystallized carbonate of soda in two-thirds of the water, and the blue vitriol in the remaing one-third, and mixing both solutions; filtering off the precipitate, dissolving in the caustic lye, and adding this solution to the other.

Electrogalvanizing.—In the *Elek. Zeit.* of Nov. 12, Grabran describes some experiments made on plating zinc on iron, especially for use with vessels. He experimented with six different solutions, and found that the best results were obtained with a solution containing 1,200 grams $ZnSO_4$, 60 grams H_2SO_4, of 24° Baume, and 6,000 grams of water. With a current density of 6 amperes per square decimeter he obtained a solid and firm deposit, the voltage at the terminals being 9 to 10 volts. The "electrochemical equivalent" is given as "0.32 milligram" with circulation; this evidently means that in his experiments he deposited 0.32 milligram per ampere second; in other words, the ampere hour efficiency was nearly 100 per cent. He describes an apparatus for plating the sides of a vessel with zinc. It is especially important that any soldered places of the sides of the ship should be plated with zinc, as otherwise local galvanic action is started. This apparatus might be described as a nozzle through which the electrolyte is circulated. At its end it has a rubber ring with which it is pressed against the side of the ship, while the anode consists of zinc in contact with the electrolyte.

Nickel Plating.—In *Erfindungen u. Erfahrungen*, vol. 30, page 518, the following prescription for an electrolyte for nickel plating is given: One kg. nickel sulphate, 715 grams ammonium tartrate, 5 grams of tannic acid, dissolved in ether, are mixed in 3 to 5 liters of very hot water, filtered and diluted with 17 to 15 liters of water. The solution must be neutral and is stated to be suitable for plating nickel on any metal.

Organic Matter in Plating Solutions.—In the December issue of *Metal Industry*, Sperry discusses the effect which the presence of organic matter in plating solutions has upon the deposit. Early in the history of copper refining it was found that certain kinds of varnishes used to protect the wooden vats greatly influenced the character of the deposit. It was found that benzoic acid, added in extremely small amounts, to a sulphate of copper solution would give a bright and tough deposit which otherwise would be dark-colored and granular. To get with a high current density a good copper deposit, gelatine may be added to the solution, in the proportion of one part of gelatine in 30,000,000 parts of solution. If too much gelatine is added the result is worse than if none at all is introduced. A solution of gelatine in dilute nitric acid is employed for the purpose. It is stated that it has been found by a certain copper producer that an infusion of oak-wood—which he calls "woodtea"—accomplishes the same result. It likewise is said to prevent the antimony from coming down with the copper and contaminating it.

Electrolytic Drilling and Slotting Process.—At the present time armor plates are often drilled by means of an electric arc, the plate being connected to one pole of the electric generator and the carbon to the other; the carbon is held over the spot to be drilled, and the iron melted out. Another process consists in softening the plates locally by applying heat by means of an electric current, the portion to be drilled being made the resistance in an electric circuit; it is then drilled in the ordinary way. The oxy-hydrogen flame is used in a similar manner, both for the actual drilling and softening. An elaboration of the oxy-hydrogen process consists of blowing oxygen at a high pressure against the portion of steel being heated by the oxy-hydrogen flame, so that the heat of combination will yield the amount of heat necessary to melt the adjoining parts, the high pressure of the oxygen carrying all the molten iron with greater velocity than the heat can be conveyed from them. It is claimed that by this method a cold steel ingot, about 15½ inches in thickness, can be perforated in about 3 minutes. In the October issue of the *Electrochemist and Met.*, Cowper-Coles describes an electrolytic drilling and slotting process which he has worked out. In his first experiments the electrolyte was projected on to the iron to be drilled, a current of electricity being sent from the metal to be drilled through the jet of liquid and back to the generator. While this method gave fairly satisfactory results, yet the holes were not sufficiently true. A nozzle was then constructed, through which the electrolyte is being rapidly circulated around a baffle plate, placed in the center of the nozzle. A pointed rod, fitted in a gland, is so arranged as to be near the end of the baffle plate. The rod forms the negative electrode, on which the iron is deposited as a powder, to the high current density, and is washed away by the rapidly circulating electrolyte. The end of the nozzle is fitted with a removable washer, the shape and size of which determines the shape and size of the pole to be drilled. While some of the best results in drilling iron have been obtained with a solution of sulphuric acid, good results have been obtained by ordinary salt water.

Electrolysis of Water.—In an illustrated article, published in *La Machine* (Geneva) vol. 5, pages 7 and 33, Fiersot describes the apparatus of Siemens & Halske for the electrolysis of water in which a 10 per cent solution of potassium carbonate is used as electrolyte. One hundred and thirty-four grams of water are decomposed per kilowatt-hour. By heating the electrolyte the output may be increased by 8 per cent. The electrolytic oxygen thus produced is in the average 97 per cent pure, while the hydrogen contains one per cent of oxygen.

Electric Furnace.—The November and December issues of *Elektrochem. Zeit.* contain the conclusion of the illustrated serial by Minet on the development and the applications of the electric furnace. He describes the aluminium furnaces of Kiliani, Hall, Gooch and Borchers; the magnesium furnaces of Fischer, Graetzel, and Borchers; and the sodium furnaces of Graubau, Borchers and Becker.

Fixation of Atmospheric Nitrogen.—A concise summary of recent investigations in this line is given in *Zeit. f. Elektrochemie*, October 29.

THEORETICAL AND EXPERIMENTAL.

Electric Potentials of Some Strong Oxidizing Agents.—In a paper published in *Zeit. f. Elektrochem.*, November 5, Scobai first gives a review of the work of various experimenters who tried to determine the potential of strong oxidizing agents dependent on the concentration of the hydrogen ions in dilute solutions. All of them experienced great difficulties, since it takes a longer time before a constant reading is obtained and the readings do not agree well together. He has now investigated whether better results can be obtained in

concentrated solutions, and has investigated under which conditions one may rely upon getting constant e. m. f's., and always the same value. The problem is intimately connected with the question of the reversibility of the reaction. He experimented with various strong oxidizing agents, like peroxide of manganese, permanganate of potassium, and persulphate of sodium in 1 normal, 12 normal, 22 normal, and concentrated H_2SO_4. While, in the cases investigated by him, no practical reversible reactions take place, yet constant values of the potential can be obtained. The value of the potential is constant for a long time, and does not, therefore, depend upon the time. If an electrode is replaced by a new one, the old values of the potential are soon obtained again. In general, the e. m. f. is independent of the material of the inert electrode. While with chromic acid the potential value was found to decrease slightly, as a result of stirring, yet the old values were soon reached again. He concludes that the potential values measured by him are really constant and not accidental, that they can be reproduced, and that they probably represent values characteristic of the oxidizing agents used.

Electric Resistance Furnace for the Laboratory.—In the *Journal de Chimie Phys.*, September, GUNTZ describes the following construction of an electric resistance furnace for laboratory use. On a tube of porous earthenware, which serves as the heating tube, he applies a layer of 5 mm. thickness of aluminate of magnesium, which does not attack platinum at a high temperature. It contains about 8 parts of weight of MgO to one of Al_2O_3. On this layer of magnesium aluminate he winds a platinum wire of about 0.3 mm. diameter, the distance between its turns being about 5 mm. Around this he applies another layer of aluminate of magnesium. The whole is covered by a layer of asbestos. The two terminals of the platinum wire, which are fixed by means of a screw on the outside layer, serve as connection for the current. The apparatus is said to stand a temperature of 1,300° to 1,400° C., with a consumption of 700 volts, the tube being 25 cm. long, and having a diameter of 5 cm.; its cost is low.

Electrochemical Laboratories.—Two descriptions are found in the *Electrochemist and Met.* of October, the one by PERKIN, of the electrochemical installation at the Borough Polytechnic Institute in London, the other of the general arrangement of the Metallurgical Institute of Aix la Chapelle in Germany. Perkin derives his working current from twelve storage cells, with 80 ampere-hours capacity, which may be connected either in series or in parallel or part in series and part in parallel. For regulating purposes he uses resistances made from insulated platinoid wire, wound on asbestos-covered brass tubes. The advantage of winding on tubes is that a current of air passes through them and serves to keep the resistance cool. The contact is a double-sliding one, and a connection is made with the resistance wire by removing the insulation from the upper and lower surfaces of the wire. Each of these resistances is about 20 ohms, and will carry a current of about 3 amperes without unduly heating. For carrying heavier currents he uses resistances made of insulated segments of copper strip, clamped closely together and connected up in series by means of spirals of platinoid wire. The resistance is regulated by means of a sliding key contact. This resistance carries from 4 to 5 amperes without becoming unduly hot. Liquid resistances are very convenient, but the solution easily becomes very hot and evaporates away.

Separation of Iron from Manganese.—In the *Chem. Berichte*, vol. 36, page 2,716, KOESTER discusses the electrolytic separation of iron and manganese. Difficulties are experienced here since always some quantities of iron are carried away with the manganese, which is deposited as peroxide. For smaller quantities of manganese, Classen recommends to reduce the formed peroxide of manganese by an addition of oxalic acid, so that the manganese is not deposited before all the iron has been separated. If, however, manganese is present in larger quantities, the oxalic acid is not sufficient to retard the deposition of manganese. The present author has found phosphoric acid to be an excellent reducing agent in this case.

Lighting of Ions.—The paper of BOLTON read before the International Congress for Applied Chemistry (ELECTROCHEMICAL INDUSTRY, 1903, page 566) is printed in full under the title "on lighting of the electrodes, and a new spectroscopic method" in the *Zeit. f. Elektrochemie*, November 19. A great number of spectroscopic results are given in form of diagrams. The number of December 17, of the same journal, contains two communications by Hoppe and Voller, claiming priority of the invention of the method.

Electrochemistry.—In two further installments of his series on the development and present condition of electrochemistry (*Electrochem. Zeit.*, November and December), NEUBURGER gives a review of the electrochemical theories before Faraday, and discusses especially the theory of Berzelius.

New Journal for Physical Chemistry.—The first number of a new journal has just appeared. The title is *Physikalisch-Chemisches Centralblatt* (Physico-Chemical Review). The editor is M. Rudolphi, and the publishers are Gebrueder Borntraeger, in Berlin. The journal will not publish original articles or papers, but is intended to be a comprehensive review of progress in physical chemistry, giving quick, thorough and concise abstracts of the original articles published in various countries in this field. In order to be complete it must be international, and for this reason a novel departure is made, in so far as the abstracts are given either in German, or English, or French. As far as possible the abstracts will be furnished by the authors themselves. As regular contributors, are mentioned on the title page, the following Americans: Bancroft, Goodwin, Jones, Kahlenberg, Loomis, Noyes, T. W. Richards and L. R. Morgan. The first number was published on December 15, and comprises thirty-two pages, on which abstracts are given of seventy-nine papers. The journal is to be published twice a month.

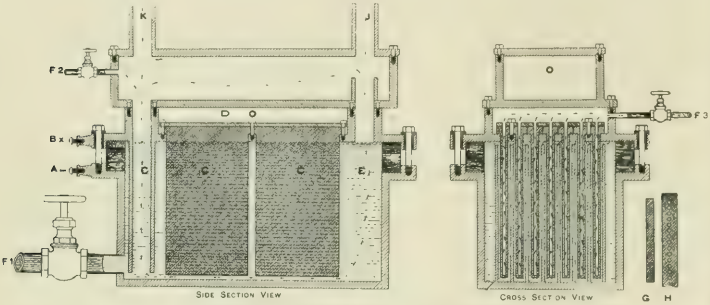
BATTERIES.

Electrolytic Formation of Lead Peroxide from Lead.—The *Centralblatt f. Accumulatorenkunde* of September 15, October 1 and 15, and November 1 and 15, contains a long article by ROKOTNITZ, on the electrolytic production of lead peroxide from lead. His results may be summed up as follows. In sulphuric acid solution the output of peroxide is very small, and nearly independent on the concentration; the ampere-hour efficiency is less than 0.3 per cent. If the electrolysis is first conducted at 2 volts for producing lead oxides, and then continued at a higher voltage, the efficiency is only very slightly better, being still below 0.5 per cent. The efficiency is improved, if the metallic lead is first treated in an ammoniacal solution; a treatment in ammoniacal solution for eighteen hours, and in sulphuric acid for thirty hours gave an efficiency slightly above 2 per cent, while a treatment of twenty-four hours in ammoniacal solution, and twenty-four hours in sulphuric acid gave an efficiency of 3½ per cent. The efficiency became much better, if such substances were added which first produced another lead compound, from which peroxide could then be formed more easily. Additions of potassium chlorate and potassium sulphate in such a degree that the quantity of the "precipitation salt" corresponds to the electrochemical equivalent, and that of the "solution salt" to the maximum conductivity of the electrolyte, produced an efficiency of 80 per cent. (This is the method of Luckow; the author used 46.7 grams of potassium sulphate and 30 grams of potassium chlorate for one liter of water.) If a smaller amount of chlorate was used with circulation of the electrolyte, the efficiency was smaller, but still good (63 per cent); with the same electrolyte, without circulation at a temperature of 60° C., it was 52 per cent; at ordinary temperature of the room 48 per cent; at 0° C. 28 per cent. If, in the same electrolyte perchlorate is substituted for chlorate, and the electrolysis is made at the temperature of the room, the efficiency is 39 per cent. Some better results were again obtained by

addition of nitric acid (49 per cent). A 7½ per cent solution of 95.5 parts of ammonium sulphate and 0.5 part chlorate in dilute sulphuric acid gave an efficiency of 32 per cent; if perchlorate was substituted in this case for chlorate, the efficiency was reduced to below 4 per cent. Alkaline solutions gave worse results than acid solutions; the best electrolyte of the former being sodium hydroxide, which gave an efficiency of 19 per cent. In the numbers of December 1 and 15, of the same journal, continuations are published of the serial of Peters, the publication of which was begun long ago, but was discontinued for some time, in which he gives the results of laboratory tests on the electrolytic formation of lead peroxide from lead. The end of the serial seems not yet near, nor is any summary given of the results.

Light Storage Batteries.—While by far most of the storage batteries placed on the market by the manufacturers are used for stationary purposes in lighting or traction stations, yet the increasing interest in automobilism has placed before the battery designer a new problem, that is to develop a light accumulator. The development of the light accumulator since 1900 is reviewed by Joly in an illustrated article in the October issue of *Electrochemist and Met.* Some notes are given concerning the following batteries: Phenix, Max, De Dion Bouton, Tommasi, Contal, Exide (Electric Storage Battery Co.), Edison, Hart, Oppermann, Leitner, Elieson, Lithanode, Rosenthal, Poppenburg, Progress, Garassino, and a few others. Concerning the Contal battery (Accumulator Electricia) it is said that its cost is moderate, and that it has a remarkably long life under the severe conditions of road traction. The plates are 103 x 120 mm. and 3.5 mm. thick, and are made in two pieces, riveted together in the mechanical pasting. Triangular bars divide each side into 252 small squares, and the plates are perforated with 252 holes, in the center of each square, respectively. In tests which were made in the Laboratoire Central in Paris in 1901, and which are said to have since been confirmed by daily practice, a 21-plate cell, weighing 13 kg., gave 150 ampere hours and 290 watt hours, at a rate of 49.2 amperes; 194 ampere hours and 384 watt hours at a rate of 32.7 amperes; 218 ampere hours and 434 watt hours at a rate of 18 amperes; 210 ampere hours and 425 watt hours at a rate of 14 amperes. Each cell carries two taper terminals, which the connections from cell to cell are made to fit, thus assuring a good contact right through.

Electricity Direct from Carbon.—The old problem of devising a carbon cell continues to attract inventors. One of the latest aspirants to honors in this line is J. H. Reid, whose patents were abstracted in Electrochemical Industry, December, 1903, pages 591 and 592. He has now given a public demonstration of his cell at Newark, N. J., an account of the exhibition being given in *Electrical World and Engineer,* December 12. Briefly, the method consists in conducting a fuel gas into a porous receptacle pervious to gas, but impervious to liquid; maintaining a heated electrolyte at the opposite face of the receptacle; supplying oxygen to the heated electrolyte, and providing conductors for the developed electricity from the porous receptacle and from the liquid electrolyte. The cell is a cylindrical iron vessel filled with an electrolyte composed of sodium hydrate, calcium chloride and iron oxide, the electrolyte being maintained at a temperature of 390° F. Penetrating into the electrolyte, and insulated from the iron are hollow electrodes, made of carbon. The carbons are of positive polarity, and the iron pot of negative polarity. Fuel gas is forced into the hollow carbons, and the contention is that it percolates through the porous walls of the carbons, the carbon and hydrogen of the gas uniting with the oxygen in the electrolyte or in the carbon wall, resulting in the production of electricity. At the demonstration, illuminating gas, mixed with air, in the proportion of one part of gas to 40 of air, was used, and the electrolyte was heated with illuminating gas. An e. m. f. of 0.9 volt was developed and maintained fairly constant, so long as the gas was passed through under the proper pressure, and the electrolyte was maintained at a temperature of 390° F. The gases escaping at the top of the cell were said to contain water vapor, carbon dioxide and carbon monoxide, and the inventor intends to return them to the combustion chamber, so as to recover the heat value of the carbon monoxide. The cell recovers very rapidly from the effects of short-circuit. The form which a commercial plant will take is illustrated diagrammatically by Figs. 1, 2, 3. Fig. 1 represents the containing vessel, which is the negative pole; *B*, the aerating and exhaust part of the apparatus being the positive pole; *C* are the porous electrodes directly-connected to the positive pole, while *D* is the gas chamber into which gases are forced and allowed to percolate through the porous electrode into chamber *E*, which is filled to line *B*, with an electrolyte. This electrolyte is an oxidant. The cock marked *F*1 is for convenience in drawing off the electrolyte, and *F*2 is a water cock for cleaning out the aerating and expansion chamber. In Fig. 2 *F*3 is a cock controlling the flow of gas, *G* is the bottom view of the electrodes, *C C h* is the top view showing gas inlets to electrodes *C C*; *I* shows the iron electrodes connected to *A* and forming the negative electrode in the electrolyte. The arrow marks in this cut show the flow of gas, and in Fig. 3 of the electrolyte to and from their openings; *J* represents the



FIGS. 1 AND 2.—REID GAS BATTERY.

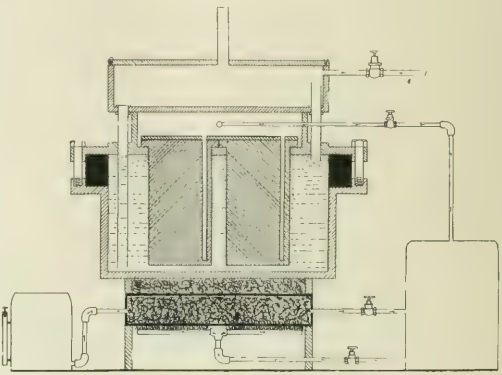


FIG. 3.—REID GAS BATTERY.

exhaust, and *K* is an intake of free air to maintain the balance of oxygen in the electrolyte. It is stated that a 100-hp outfit made up of ten cells will be exhibited publicly some time in January. This, it is claimed, will be a practical and commercial apparatus, and will be submitted to a committee of experts. It is stated that it will occupy a space 8 x 8 x 10 feet long, and will include, besides the cells, a complete gas generating plant. As the e. m. f. will be but 10 volts, a current of 7,460 amperes will be generated. (A critical discussion of the scheme of the Reid cell will be found in an article of Mr. C. J. Reed, published on another page of this issue.)

MISCELLANEOUS.

Estimating Gold in Working Cyanide Solutions.—The determination of gold in cyanide solutions by evaporation and fire assay, although possessing considerable accuracy, is an extremely cumbrous and lengthy process, especially when very weak solutions are dealt with. In consequence of this fact control of the zinc precipitation of gold is rendered difficult, for the reason that the assay of the liquor from the foot of the zinc boxes is frequently not obtainable before the next day, by which time the solutions may have become seriously deranged, for example, gold-bearing solution may have been used for leaching. In the *Journal of the Chemical, Metallurgical and Mining Society of South Africa,* of September, MOIR describes a method of detecting traces of gold in the state of auro-cyanide in less than twenty minutes. The principle is "to precipitate the gold by means of the strongest available galvanic couple in a medium which destroys the cyanides and keeps the ferro-cyanides and other common impurities in solution. The metallic gold is then dissolved in aqua regia and tested for with stannous chloride in the usual way. The different intensities of color obtained are sufficiently distinct from one another to enable an estimation of the gold, within a few grains, to be made by comparison with a graduated color-wedge, or a set of standard colors, and after a little experience one can dispense with these and estimate within less than 0.2 dwt. by eye alone." The process, in detail, is as follows: 100 cc. of the cyanide solution is poured into an evaporating basin (of not more than 300 cc. capacity), treated with one or two grams of sodium peroxide, and boiled for two minutes to destroy the cyanide. The quantity of peroxide and length of time of boiling is varied according to the amount of free cyanide present. Next, two drops of lead acetate solution (10 per cent) are added, whereon a brown spot of PbO_2 forms and re-dissolves, showing whether enough Na_2O_2 has been employed. Next, the flame is removed and a small quantity (about 0.1 gram)of aluminium powder is added and the mixture vigorously stirred until hydrogen ceases to come off. If the aluminium is pure the liquid will not require to be heated. What happens is that metallic lead is first precipitated and the aluminium-lead couple electrolyses the auro-cyanide, so that finally we have a black precipitate, consisting of lead and gold, whilst the liquor no longer contains cyanide. The mixture is filtered through a small paper, and the dish rinsed out into it. This is very easy, with so alkaline a solution. The filtrate is rejected. Next, 10 cc. of aqua regia is warmed until it turns yellow and poured into the paper, and the filtrate is collected in a test tube, boiled and poured through the paper again. This is repeated until the filter paper is perfectly clean, whereon it is washed out with a small quantity of water. The yellow filtrate is then treated with strong stannous chloride solution, added drop by drop, until the yellow color has faded. If the original cyanide solution contained over 5 dwt. of gold, the purplish-blue shade appears at once, but if only a few grains of gold per ton were present the mixture must stand a few seconds. After half a minute the full intensity is attained, and the comparison with the standards is made. For exact work the solution is poured into a cylinder exactly one inch in internal diameter, and made up to a definite volume, say, 15 cc., with water, before making this comparison. The purple solution fades through oxidation on keeping, and, therefore, cannot be used for a standard. He, therefore, uses a permanent imitation of the shade, made by adding copper sulphate solution to cobalt nitrate solution until the exact tint is obtained; the mixture is diluted for use and standardized by the results of the foregoing process applied to cyanide solutions of known gold-content.

For the range between 0.5 and 2 dwt. per ton, the most convenient standard is an "indigo-prism" or triangular bottle, which, when filled with the above-colored fluid, affords a gradually varying thickness of liquid, and can be graduated empirically once for all, so as to read directly in dwt. per ton. This is held horizontally and moved across the cylinder at the level of the gold-containing liquid until its color is matched, when the value is read off. Some practice in matching colors is required in order to read to 0.1 dwt., but without practice one can read to 0.2 dwt. Of course, it is more satisfactory to keep a set of standard tubes (15 cc. in tubes of constant diameter differing in value by, say, 3 grains), but this takes a longer time to prepare. For quantities under 10 grains per ton it is best to look down the tubes and make the comparison exactly as in "Nesslerising." The lower limit is about two grains per ton, but if one starts with a larger quantity of the original cyanide solution than 100 cc. is proportionately increased, as the gold is still concentrated into the final 15 cc. Thus, if 500 cc. be taken, the limit is about 0.4 grain per ton (one part in thirty-five millions.) It should be noted that the differences of intensity are less marked for the darker solutions; anything over 3 dwt. per ton gives a nearly opaque solution. Therefore, if the solution to be tested is known to be strong, only 50, or even 25 cc. should be taken for the experiment, diluting to 100 cc., and multiplying the result by two or four, respectively. As a check against the occurence of incomplete precipitation of the gold, it is advisable to test the filtrate from the lead with $FeSO_4$ and HCL for cyanide, which should be absent in a successful experiment. The best mixture for aqua regia is 100 cc. concentrated nitric acid, 300 cc. concentrated hydrochloric acid, and 400 cc. water. For the benefit of those who have not sodium peroxide at their disposal, the author has introduced the following modification. A solution is made of 30 per cent NaOH and 0.1 per cent litharge. Ten cc. of this is boiled with 100 cc. of cyanide solutions for five minutes, then the aluminium is added and the rest of the process is the same.

Welding Aluminium.—The problem of making an efficient and durable aluminium joint is of great importance for the practice. In the November number of the *Electrochemist and Met.,* COWPER-COLES gives some illustrated notes on the welding of aluminium. He claims that soldered aluminium joints have proven unsatisfactory, and describes the welding processes of Dick, Heræus, Emmé, Schmidt, and Jones' process for welding aluminium tubes. He thus describes at greater length his own process, in which no flux or solder is used, and which does not necessitate the hammering of the joint when in the semi-fluid state. The process is stated to be especially suitable for wire rods and tubes, and other turned or rolled sections, and consists in placing the parts to be soldered, after being faced off square in a machine fitted with clamping screws which are capable of moving horizontally on suitable guides. The motion of the clamping screws is controlled by levers. The aluminium to be welded is heated by means of an ordinary benzine lamp, and as soon as the rods have arrived at the necessary temperature, slight pressure is supplied to the levers mentioned before, which causes them to unite, and a ring of metal is squeezed out. This ring is largely composed of aluminium oxide, and acts as an insulating supporting collar, the molten metal being retained within this collar. The weld is then instantaneously quenched by turning a handle attached to a screen which allows water under pressure to be projected on to the joint from a reservoir. The same handle which turns the water on, places a screen in front of the heating flame, the rod is then removed from the machine and

the collar is filed off. The joint is claimed as strong as the rest of the metal.

Electric Pyrometer.—While in the early days of the electric furnace the intention always was to get as high a temperature as possible, the later development of furnace design has led to an elaboration of methods for controlling the temperature in the furnace, so that it remains between given limits. The reason is that the temperature is generally the main factor which determines the end product of a furnace reaction. Under these circumstances the importance of reliable means for measuring the high temperatures in a furnace correctly is quite evident. The London *Electrician*, of November 6, contains an illustrated description of a pyrometer made by a British firm. It consists of a coil of platinum wire, wound upon a cylinder of refractory material, and usually fixed at the end of a long closed iron tube, where it is protected by a platinum shield, for measuring the resistances of the coil, in order to ascertain the temperature. The temperature is thus measured by determining the change of the electric resistance with the temperature. Two different arrangements are used. One comprises a differential galvanometer and a set of resistance coils, and gives readings in ohms and the temperatures corresponding thereto are ascertained by means of special tables. The second arrangement, which is shown in Fig. 3, is a combination of a simple d'Arsonval galvanometer and a Wheatstone bridge, with a circular resistance and sliding contact, and it gives readings directly in thermometric degrees. It is claimed that both types give very accurate readings. Their principal field of application lies with iron, steel and similar processes, the temperature of which has to be constantly watched and regulated. In the instrument of the first type described above, a change of the resistance from 10 ohms to 44.9 ohms, corresponds to a rise in temperature from 58° F. to 2,204° F.

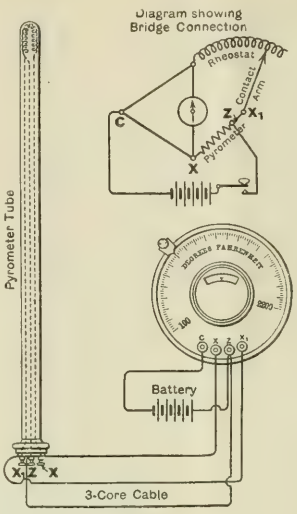


FIG. 3.—PYROMETER

Acetylene.—A paper by KUCHEL, giving practical notes on the construction of acetylene central stations, and of the network of tubes for distribution of the acetylene is given in the *Zeit. f. Calciumcarbid Fab.*, November 20 and 27. The numbers of December 4 and 11, of the same journal, contain a description by FOUCHE of a new acetylene-oxygen burner for soldering purposes.

Gibbs.—The December number of the *Physical Review* contains, from the pen of J. E. TREVOR, an account of the life of Josiah Willard Gibb, with a concise analysis of the contents of his most important thermodynamical papers.

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By GEORGE P. SCHOLL, PH. D.

ELECTRIC FURNACE AND FURNACE PRODUCTS

Metallurgical Process.—O. W. Brown, Bloomington, and W. F. Oesterle, Marion, Ind. Patent 742,830. November 3, 1903. Application filed May 14, 1903.

The process relates specially to the treatment of zinc blende in the electric furnace. In carrying out the process the inventors state that they mix carbon (coke or coal) and lime with the zinc blende, in proportions varying with the purity of the ore and the by-product desired. The mixture is placed in the electric furnace and heated in the usual manner to a sufficiently high temperature, whereupon, as the inventors say, the zinc is reduced to a metallic form and volatilized out and condensed in the usual way, while the carbon and the calcium are saved, together with the sulphur, in the form of calcium carbide and carbon disulphide.

Method of Melting Glass.—J. T. C. Kessmeier, Washington, Pa. Patent 745,863, December 1, 1903. Application filed November 14, 1902.

The object of the invention is to provide means whereby glass may be rendered so soft and fluid that it can be made to flow from a tank or furnace into molds with deep and narrow cavities. The glass is melted in a tank, furnace, pot or other suitable receptacle by the heat derived from burning fuel; it is allowed to flow from the melting furnace, and as it flows it is superheated to a very high degree, 3500° F., or more by means of an electric current, so that it will reach the molds in a state of extreme fluidity. The tank is of ordinary construction, and is provided with a cylindrical conduit through which the glass flows when a plug, which closes the conduit ordinarily, is withdrawn. On opposite sides of this conduit there are arranged holes through which pass carbons, which are fed against each other by a mechanism, the same in construction and operation as the feeding mechanism of an electric arc lamp. A current of approximately 5 amperes for each square millimeter of electrode surface at 300 volts is conveyed to the carbons. When a casting is to be made, the plug is withdrawn from the conduit and the carbons brought together so as to form the arc. The glass, as it flows through the conduit, comes in contact with the carbons and is superheated and rendered very soft, so that it will flow into the molds like molten metal. The mechanism for feeding the carbons towards each other, as they are consumed, is only necessary when very large castings are to be made, or when the molds are filled in rapid succession, as the arc will be maintained for considerable time, before the carbons are consumed to such an extent as to break it.

Electric Furnace.—W. S. Franklin, South Bethlehem, Pa. Patent 742,852. November 3, 1903. Application filed December 3, 1900.

The furnace described in the specification is shown in the accompanying Fig. 1. It consists, essentially, of a block of masonry A, in the lower portion of which is formed a pear-shaped chamber B, which, at its upper end, connects with a cylindrical passage C. The upper end of the latter is widened out in the form of a cone, which serves for the introduction of the materials to be treated in the furnace. A layer of carbon, metal or other suitable conducting material, preferably in the form of plates, is built into the wall of the furnace and extends around the circumference of the chamber B. This layer forms one of the electrodes of the furnace. The second electrode F is constituted by a bar of carbon, metal or other suitable material, and it has a number of teeth f' on its circum-

ference, which point downwards. H and G are tapping holes. In the operation of the furnace, a portion of the chamber B is stated to be filled with a molten electrical conductor I, which has a high electrical resistance. Slag or glass are said to be suitable for such purpose. The upper electrode can either be dipped into this conductor, in which case the heating is mainly done by resistance, or it may be raised above its surface, and in this case the heating will also be accomplished by the arc formed between the electrode and the surface of the molten material. The electrode is shown supported upon an eccentric, so that it can move up and down, and its downward stroke carry the charge down. In the reduction of iron ores the material for the molten conductor is preferably slag. The usual charge containing the ore is fed into D, preferably at intervals, as the latter method is stated to enable the charge of ore, coal, limestone, etc., to be fed separately, and to be accurately regulated in quantity. The operation is described as follows: "As the charge passes downward the ore is reduced during its descent by the heat ascending from the molten conductor, or from such conductor and the arc, according as the carbon rod is immersed or not in the molten conductor.

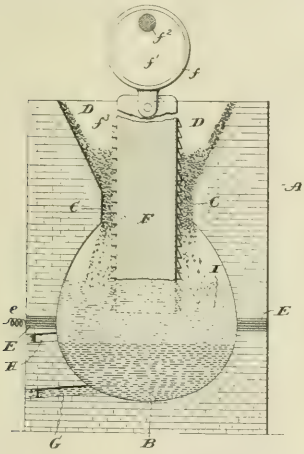


FIG. 1.—ELECTRIC FURNACE.

When the ore reaches the intensely hot slag, it melts and filters through the slag to the bottom of the receptacle B, where it collects. The iron is drawn off as desired through the lower vent, and the slag is kept at the proper level through the upper vent." If the furnace is to be used for glass-making, the lower portion of the chamber B is lined with carbon, or other conducting material.

Process of Producing Carbon Chlorides and Silicon.—F. J. Machalske, Brooklyn, N. Y. Patent 745,637, December 1, 1903. Application filed September 16, 1903.

The process consists in reacting on a carbon compound, such as carbon bisulphide or methane, with a chloride of silicon, usually the tetrachloride, under such conditions that the silicon and carbon interchange and the resulting carbon chloride is driven off. The reaction is effected in the electric furnace in a non-oxidizing and dry atmosphere. In the case of carbon bisulphide the reaction produces silicon bisulphide, which may be readily reduced to metallic silicon by heating it with carbon. The apparatus, used for carrying out the process comprises, in the first place, an electric furnace, composed of a stack lined with magnesia brick, suitably provided with electrodes, preferably of metallic silicon. Charge opening, outlet and tapping-hole are provided also. For the production of silicon tetrachloride the furnace is charged with a water-free mixture of silica, preferably sand, and an alkali chloride, preferably sodium chloride. An electric current is then passed in order to heat the mixture to a sufficient temperature to effect the reaction. The gaseous silicon tetrachloride escapes and the molten residue of sodium oxide is tapped off. The silicon tetrachloride is conducted into a mixing chamber, which is situated above a second electric furnace, of similar construction to the first. This furnace is used to produce carbon bisulphide, from a charge of carbon and sulphur. The vapors of the carbon bisulphide rise and mingle with those of silicon tetrachlorides, and the resulting mixture passes into another electric furnace. The latter has the purpose of heating the mixed gases to the temperature necessary to effect the reaction between them. One or more pairs of electrodes, which may be of carbon, platinum, etc., are arranged to heat the gas mixture by means of arc sprung between the ends of the adjacent electrodes. The carbon chloride finally escapes through an outlet flue, and the silicon sulphide produced may be withdrawn through the tapping hole. The latter may be conveniently employed by charging it, mixed with an equivalent amount of carbon, into the second electric furnace, instead of or as an addition to the charge of carbon and sulphur. The metallic silicon produced by the reduction may be drawn off through the tapping hole of this furnace. It is stated that methane or other carbon compounds may be substituted for carbon bisulphide as a source of carbon. When a mixture of one combining weight of silicon tetrachloride and methane is heated to the proper temperature in the third furnace, the silicon and carbon interchange according to the equation, $SiCl_4 + CH_4 = CCl_4 + SiH_4$. This hydride of silicon may be advantageously used for the production of finely divided silicon carbide or carborundum, by burning the hydride in an atmosphere of carbon dioxide. The reaction taking place then may be expressed by the equation, $SiH_4 + CO_2 = SiC + 2H_2O$.

APPARATUS AND PROCESSES FOR THE ELECTROLYTIC PRODUCTION OF METALS AND COMPOUNDS.

Electrolytic Apparatus.—E. Hannon, Brussels, Belgium, assignor to the Solvay Process Co., Syracuse. Patent 742,863, November 3, 1903.

Electrolytic Process.—E. Hannon, Brussels, assignor to the same. Patent 742,864. Both applications filed October 4, 1898.

The process and the apparatus described in the two specifications are primarily intended for the electrolysis of alkaline chlorides by means of mercury. The apparatus is illustrated in Fig. 2. It consists of a receptacle A, which contains the

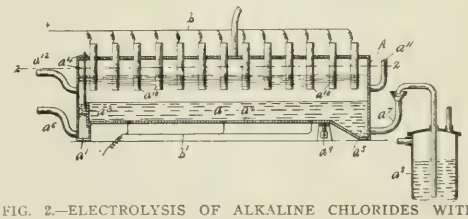


FIG. 2.—ELECTROLYSIS OF ALKALINE CHLORIDES WITH MERCURY CATHODE.

electrolyte, and a fluid electrode, such as mercury. The latter is admitted into the reservoir a^5, situated within the above receptacle, through a pipe a^7 entering at the bottom. This pipe is in connection with a supply chamber, from which a suitable quantity of mercury can be forced by pressure. At the other end of the apparatus is a wall a^3, the height of which can be regulated by screws a^4, which wall divides the vessel into two compartments, a, a'. The level of the mercury in a' is lower than that in a. The upper portion of the mecury, which contains most of the amalgam, overflows into the compartment a', whence it is removed by means of pipe a^8. The arrangement of the anodes a^{10}, and the supply and discharge pipes for the electrolyte, are clearly shown in the illustration. The screw a^9,

fixed on the bottom of the apparatus, is provided for the purpose of tilting the latter if it is desired to remove all the mercury. Means for discharging the amalgam are not shown.

Manufacture of Sodium.—T. Ewan, Glasgow, Scotland. Patent 745,958, December 1, 1903. Application filed April 18, 1903.

The process is briefly described by the inventor as follows: "Sodium hydroxide is fused in a suitable vessel, and a current of electricity passed through it between electrodes, between which a porous diaphragm is placed in such a way, that the electrolyte surrounding the cathode is prevented from mixing readily with that surrounding the anode. The porous diaphragm is made of alumina, or of sodium aluminate, or of mixtures of these substances. Sodium, together with a very small quantity of hydrogen, is formed at the cathode. Oxygen and water are formed at the anode. The removal of the water from the fused electrolyte surrounding the anode is facilitated by passing a current of air or other suitable gas through or over it."

Electrode and Conductor.—C. E. Acker, Niagara Falls. Patent 743,410, November 10, 1903. Application filed June 5, 1902.

The invention relates to the construction of a carbon electrode designed specially for use in electrolytic operation, where high-current densities are employed. It is illustrated in Fig. 3, and consists essentially of a carbon block 1, the lower surface of which is provided with grooves. The latter serve the purpose of facilitating the escape of gases. 2, 2 are carbon shanks, protected by tubes 4, 4 of fire clay or other refractory material, in order to prevent access of air to the heated carbon. The carbon shanks are connected to a conductor 3 by means of the rods 5, 5 and the yoke 6. In order to protect also the juncture between the carbon shanks and the metallic conductors, slabs of scrapstone are united by plates or grids 8 into a casing, the interior of which is filled with cement 9. This refractory casing is of somewhat greater area than the block 1, so that, when a series of electrodes is assembled in a furnace, the carbon blocks are sufficiently far apart to permit the furnace charge to be fed between them. A specific example of the use of the electrode is given, when the electrolyte is sodium chloride, which is maintained in fusion by the current. The carbon blocks may be 8¾ inches wide by 13½ inches long by 4 inches thick, the lower or working face of each having an area of approximately 118 square inches. The current density may vary from 20 to 25 amperes per square inch of working face. For an electrode block of this size and the above current density, the shank should consist either of one carbon rod, 6 inches in diameter, or of two rods, 4¼ inches each in diameter. It has been found that the best material for the purpose is a carbon composition, which is not moulded, but forced through dies under heavy pressure. Both the anode blocks 1 and the shanks 2 are formed of this material, which may be graphitized to increase their conductivity and to facilitate tooling.

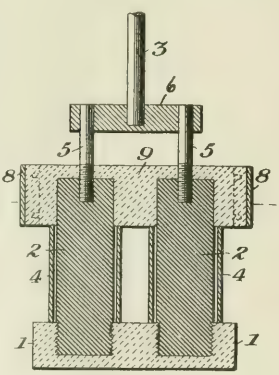


FIG. 3.—ELECTRODE.

Coating Glass or Fabrics.—H. Keppler, Brooklyn, N. Y. Patent 743,522, November 10, 1903. Application filed February 21, 1903.

In carrying out this method for depositing metal on glass, fabrics and other material, the inventor first mixes medium bronze lacquer with "illuminous powder and applies it evenly over the surface of the glass. This process gives the surface a frosted appearance and makes it act as reflector, f. i., when applied to the upper half of an electric light globe. In coating fabrics the lacquer only is applied and the powder omitted. The second step consists in mercerizing white rubbing varnish and applying the latter evenly over the first mixture. This surface before drying is dusted over with gold bronze powder and dried. The final step consists in subjecting the article thus coated to a copper bath, after which it may then be painted or enamelled. When the process is applied to laces or fabrics, the inventor states that the latter materials retain to a surprising degree their pliability.

Extracting Chromium from Chrome Iron Ore.—R. Suchy and H. Specketer, Griesheim-on-the-Main, Germany, assignors to Chemische Fabrik Griesheim Electron. Patent 743,668, November 10, 1903. Application filed February 6, 1903.

The inventors have found that chromium can be extracted from the chrome iron ore in a very simple manner, by treating the latter in hot acid solutions with oxidizing agents, such as peroxide of manganese, permanganate, chromic acid, etc. They explain the dissolving action of these agents by their oxidation of the protoxide of iron contained in the chrome-iron ore to peroxide. In carrying out the process they take 200 kg. of chrome-iron ore and about double that quantity of sulphuric acid, which is required for combination with the bases of the ore to form salts. To this is added a quantity of chromic acid in excess of that required to oxidize the protoxide of iron and the mixture is heated to 120° to 150° C. The excess of sulphuric acid is stated to form chromo-sulpho acid ($Cr_2(SO_4)_3 H_2SO_4$) from the sulphate of chromium, and the iron will be precipitated at about 150° C as white sulphate of iron. The two can thus be readily separated by filtration. Instead of using the amount of oxidizing agent necessary for the dissolution of the ore, the inventors propose to use a smaller quantity and to constantly regenerate it by electrolysis. They add to the chrome-iron ore and the sulphuric acid a small quantity of sulphate of chromium or sulphate of lead or other salt capable of being brought to a higher degree of oxidation by electrolysis. This mixture is heated while an electric current is passed through it, and chromic acid is thus produced, which dissolves the chrome iron ore, while it is thereby reduced again. By the electrolysis the oxidation is kept going on until all the ore is dissolved. The process is carried out in a closed vessel, provided with a heating jacket and an agitator, and having electrodes at opposite points, suitably insulated.

Anode Hook.—F. W. Cann, Brooklyn, N. Y. Patent 745,479, December 1, 1903. Application filed April 9, 1902.

The inventor constructs his anode hook of two parts, which are connected by threads and a coupling sleeve. The upper part is preferably of copper and bent into the shape of a hook, so as to engage the current conducting rod above the bath. The lower part is threaded into a socket in the top of the anode plate. The lower part is of the same metal as the anode, and when eaten away to a considerable extent is simply replaced, while the upper part is left intact and does not have to be also thrown into the scrap, as is the case when the anode only consists of a single piece.

Storage Batteries.

Galvanic Cell. Lothar Fiedler, London, England. Patent 738,718, September 8, 1903. Application filed December 22, 1902.

The cell described in the specification consists of a rectangular outer containing vessel of a suitable insulating material, which contains a rectangular tube of lead provided with a coating of peroxide on both sides. A negative electrode of zinc, constructed in a peculiar manner, is opposed to the posi-

tive electrode on both sides. Spaces left between the electrodes are filled with an electrolyte of the following composition: 1000 grams of a 24° Bé. solution of sodium silicate, 3000 grams of a 33° Bé. solution of sulphuric acid and 50 grams of mercuric sulphate. After this solution is compounded it is at once poured into the cell, where it solidifies to a jelly. The cell is stated to have an e. m. f. of about 2.5 volts, may be discharged to 1.6 volts and recharged in the same manner as the usual form of secondary cell.

Galvanic Cell. Lothar Fiedler, London, England. Patent 738,719, September 8, 1903. Application filed December 22, 1902.

The invention relates to a way of preparing the surface of the zinc electrodes used in the cell described in the preceding specification, and in general in cells of the zinc-lead peroxide type, in order to prevent the zinc from being destroyed by the electrolyte. The process of preparing the zinc electrode is described as follows: A plate of zinc, carbon or other insoluble conducting material is treated as the cathode in a bath of approximately the following composition: Zinc sulphate 1000 grams, mercuric sulphate 50 grams, potassium cyanide 10 grams, made up with water to 30° Bé. The anode may be carbon or zinc; in the latter case zinc sulphate is omitted from the solution. Any other cyanogen containing compound is said to answer the purpose. The action taking place in electrolysis is explained as follows: "The cyanogen set free from the potassium of the potassium cyanide combines with the zinc of the zinc sulphate forming zinc cyanide, CyZn (!), which, combining with the mercury liberated from the mercuric sulphate, forms a "mercuric cyanide of zinc," CyZnHg (!), or "cyanide" zinc amalgam, and a solution containing potassium (!!) and sulphuric acid. The mercuric cyanide of zinc or cyanide zinc amalgam is deposited on the cathode in a firm, even and porous condition." Why the cyanogen liberated at the anode should perform these difficult feats at the cathode, or why the CyZnHg (!) of the inventor should travel bodily to the cathode is a question the inventor does not trouble about. His electrolytic notions appear to be on a par with his chemical ones.

Composition of Matter for Battery Electrolytes. W. Peto and W. T. Cadett, Ashlead, England. Patent 735,808, August 11, 1903. Application filed March 14, 1903.

The inventors propose a plastic or semi-solid electrolyte, which is to take the place of the liquid electrolyte at present in use in storage batteries. It consists of powdered or precipitated sulphate of lead moistened with dilute sulphuric acid of about the average strength used in storage batteries. The two are combined in the proportion of about one pound of finely precipitated sulphate of lead to four ounces of dilute sulphuric acid of about 1.2 specific gravity. They are thoroughly mixed until they form a soft plastic mass of a paste-like consistency. The above proportions are stated to be subject to variation, but the requisite proportion of the acid can be easily regulated by allowing the mixture to stand for a while, when the superfluous acid will rise to the top and can be poured off. Sufficient acid ought, however, to be used so as to render the mass soft and plastic, for if it is too stiff, air spaces might be formed by the gassing of the cell, which might impair its efficiency.

Accumulator.—W. Kennedy-Laurie Dickson, London, England. Patent 741,675, October 20, 1903. Application filed May 16, 1901.

The cell consists of a containing vessel of hard rubber, glass, etc., lined with a metallic conducting lining from the surface of which thorn-shaped spines project. A layer of active material is firmly pressed to this metallic lining, the thickness of the layer being about equal to the length of the spine. The negative electrodes are made by taking a core of hard rubber, which has numerous perforations, and surrounding it with a hard lead or other metallic sleeve with spines similar to the above. Around this sleeve is placed a layer of paste or other form of material adapted to be formed into active material. After this layer has been applied, the whole electrode is subjected to great pressure, and is afterwards encased in a sack of asbestos. The positive electrode is formed of a solid metallic core resembling in cross-section a maltese cross, surrounded by a layer of active material and compressed into square shape with concave sides, so as to fit in between the round negative electrodes.

Storage Battery.—C. W. Kennedy, Rutledge, Pa. Patent 741,044, October 13, 1903. Application filed March 21, 1902.

The cell is composed of a series of bottomless trays of rubber or other non-conducting material. These trays are adapted to receive metallic containing cells, which carry composite plates which form the positive and negative electrodes. The containing cells are made of sheet lead, shaped to form an angular concaved bottom. The convexity of the outer surface of the cell serves to dissipate the gas or air bubbles.

Electrolytic Apparatus.—H. B. Ford, New York. Patent 745,588, December 1, 1903. Application filed May 11, 1903.

The principal application of the invention is the construction of secondary batteries. A cell constructed according to the invention is shown in horizontal section in Fig. 4, two positive and two negative elements being shown. Each negative pole element is enclosed in a porous vessel 10, preferably of wood. A conducting plate of copper is enclosed between two zinc plates, all three plates being corrugated vertically, the depth of the corrugations being substantially equal to the internal width of the porous vessel 10. A quantity of mercury is placed into the porous vessel. Assuming the internal dimensions of the cup to be 8 by 5½ inches, and the thickness of the three sheets of zinc and copper to be one-twentieth of an inch, five ounces of mercury will be sufficient. The positive pole electrode is composed of a perforated and corrugated supporting plate 15, which may be of lead with mechanically applied peroxide of lead, or of copper with peroxide of manganese.

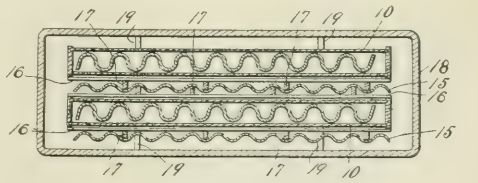


FIG. 4.—STORAGE BATTERY.

Between each positive and negative element is a separating frame, composed of horizontal strips 16, and vertical strips 17, permitting the free circulation of the electrolyte. It is stated that the initial charging current causes the mercury to act upon the zinc and the copper plates in the usual way, and to form, by the absorption of hydrogen, a sponge, containing also some zinc, which sponge expands until the porous cup is practically filled. In the discharge of the battery there is said to be double action of the oxygen upon the zinc and the absorbed hydrogen, the action upon the hydrogen being first completed and resulting in the disappearance of the sponge. As long as the latter remains, the voltage is about 2.5, and upon its disappearance the e. m. f. drops to about 1.5 volts. Dilute sulphuric acid of 25° Be′ may be used as an electrolyte. The five ounces of mercury contained in the porous cup will form upon a full charge a quantity of sponge sufficient to practically fill the cup, the sponge being too soft to adhere to the electrodes, but being retained in contact with them by the walls of the cup. It is stated that if an amalgam hard enough to be retained in grooves or pockets, as proposed before, were used, much hydrogen would be lost.

MISCELLANEOUS.

Composite Metal Roll.—C. J. Reed, Philadelphia. Patent 741,413, October 13, 1903. Application filed April 4, 1902.

The rolls described in the specification are intended to be used in the manufacture of paper, and for other operations, where a roll with a hard, smooth and substantially non-corrodible surface is required. The roll is prepared in the following manner: A drum of a base metal, like cast iron, is first coated with a solder, preferably by rotating it in a molten mixture of equal parts of tin and lead. It is then allowed to cool, and is provided with a covering of brass, copper or other non-corrodible material, by closely winding a wire or ribbon of these materials, preferably of rectangular cross-section, upon it, after the wire is first coated with solder. The structure is then heated in order to make the covering closely unite to the drum. The covered drum is then turned true and electroplated with a suitable metal or alloy, like copper, nickel or brass. A tank is shown in the specification, which is filled with a mixture of a liquid electrolyte and a granular non-conducting substance, such as sand, in which the drum is polished and plated simultaneously.

Correspondence.

ALUMINIUM AS AN ELECTRICAL CONDUCTOR.

To the Editor of Electrochemical Industry:

Sir—With reference to the comments published on page 547 of your November issue, upon the results obtained in my exposure tests, may I point out that the exposure tests commenced at St. Helen's were abandoned in 1900, and that only the series of exposure tests at Waterloo were carried on for the full period of three years.

There are no chemical works in the neighborhood of Waterloo, and sea air alone can be regarded as the cause of the corrosion of my rods and wires. John B. C. Kershaw.

Waterloo, Liverpool.

AMERICAN ELECTROCHEMICAL SOCIETY ELECTION.

To the Editor of Electrochemical Industry:

Sir—Nominations for officers of the American Electrochemical Society, to be elected in April, have already been received by the secretary, renominating me as secretary for another year.

I take the earliest opportunity of informing members of the society that it would be impossible for me to serve another year, if elected, and requesting them not to waste their nomination votes on me for that or any other office.

Charles J. Reed.

Philadelphia, Pa.

Book Reviews.

Das Neue Institut fur Metallhuettenwesen und Electrometallurgie an der Koeniglichen Technischen Hochschule zu Aachen. By Dr. W. Borchers. Halle, a. S.: W. Knapp. Price $2.00

This small book describes the new building devoted to mining and metallurgy, and gives some account in a modest sort of way of the author's labors in his old laboratory. The different furnaces are described with detailed drawings and offer opportunity for many interesting experiments. For instance, who would not like to study the rate of oxidation of copper matte or pig iron in a small converter, so arranged that the percentage of oxygen in gas blown through could be varied from 20 per cent to 100 per cent O.

In reading this book we are struck with the growing complexity of metallurgy. Separations of metals can be made in so many ways, and the metallurgical processes are increasing at an increasing rate. For instance, oil, hydraulic, pneumatic, electrostatic, and electro-magnetic separations can be used on ores, or richer products. Roasting can be done under several conditions. Reverberatory smelting or cupola smelting under oxydizing or reducing conditions can be cited also. Smelting in an electric furnace or electrolyzing at high temperature are other metallurgical means. Then there are the various chemical treatments with solvents, etc., as cyaniding for gold, and electrorefining.

The man who has the ability to use the best of these means for reaching his end, must have a scientific mind to comprehend the scientific facts and must have the ability to discriminate between reactions that work well "in microcosmo" but fail on a large scale, and those which work better in a 50-ton vat than in a beaker. Such is the position of the twentieth century metallurgist.

For those who need hints for a metallurgical laboratory this book would be valuable.

THE EDISON NICKEL-IRON STORAGE BATTERY.

Mr. Thomas A. Edison's invention of a comparatively very light and extremely durable storage battery, which would be especially suitable for automobile purposes, was first announced by Dr. A. E. Kennelly in a paper read before the American Institute of Electrical Engineers in May 21, 1901. The most interesting point was the announcement that Mr. Edison's new battery meant a radical departure from the lead cell. The new cell was characterized by Dr. Kennelly as an "oxygen lift" cell, for the reason that the chemical action in the cell during charge and discharge consists essentially in a transfer of oxygen from one plate to the other in such a way that the electrolyte—a solution of a caustic alkali—serves only as the "channel" through which the oxygen is lifted, while the one plate is changed to a higher state of oxidation, and the other to a lower state.

At first sight it looks as though a great many varieties of such oxygen-lift cells were possible. As electrolyte, an aqueous solution of potassium hydroxide or of sodium hydroxide might be used, while for the electrodes any metal would be suitable which is easily oxidized, and which, in all states of oxidation, is absolutely insoluble in the electrolyte. This last point—the insolubility of the electrodes in the electrolyte—is really the fundamental technical problem which was to be solved in the invention of an oxygen-lift cell, not on paper, but for practical use.

We may now, for a moment, assume that we have an oxygen-lift cell M. KOH, RO, where M and RO are the two electrodes, and KOH the electrolyte. M and R are assumed to be two metals, which, together with their oxides, MO and RO, are absolutely insoluble in KOH. When the cell discharges, the direction of the current through the electrolyte is from M to RO and the action of the current consists in a traveling of K ions towards the RO plate, and of OH ions towards the M plate, with a resulting reduction of the RO plate, according to the equation

$$RO + 2K + H_2O = R + 2KOH$$

and oxidation of the M plate according to the equation

$$M + 2OH = MO + H_2O.$$

The total electrochemical action in the battery is, therefore, given by the equation (obtained by summation of the last two equations)

$$M + RO = MO + R.$$

The reaction of the oxygen-lift battery is thus simplicity itself, and this is really the foundation of its special advantages.

Mr. Edison, in a very extended and systematic series of experiments, carefully considered what elements would be suitable for M and R, and soon established that the choice is very limited, on account of the requirement that these elements in all states of oxidation must be insoluble in KOH. As well

known, he has finally adopted nickel and iron; during discharge a higher oxide of nickel is reduced to a lower oxide, while the iron is oxidized.

Mr. Edison's claim is that he has been the first to construct an oxygen-lift cell which is really an oxygen-lift cell; that he has been the first to prepare electrodes which are really insoluble and active in the caustic potash solution when used continually in practice.

It is true that before the announcement of the Edison battery, others have had the idea of an oxygen-lift cell. Especially Mr. E. W. Jungner, a Swede, has taken out some patents in this direction, and Mr. T. von Michalowski has patented a method of making nickel oxide electrodes (although he uses a soluble zinc plate as the other electrode, and thus has not an oxygen-lift cell). But these were not the first ones working in this line. The general idea of oxygen-lift cells is still older. In a French patent (233,083, 1893), Darrieus explains quite clearly the general scheme. But what Mr. Edison claims, is that none of those who worked in this direction, before him, ever made a battery which turned out to be in practice what it was claimed on paper; that none of the methods described before him for making the electrodes for such purposes, would yield an active material, really insoluble in the electrolyte. To explain the situation, comparison might be made with the endeavors to design a "carbon cell;" the general scheme of such a cell is well known, and has been taken up by numerous inventors, so that when a carbon cell should really be invented some day in future, many would probably claim priority; yet it is a fact that so far nobody has made a carbon cell which would work in practice.

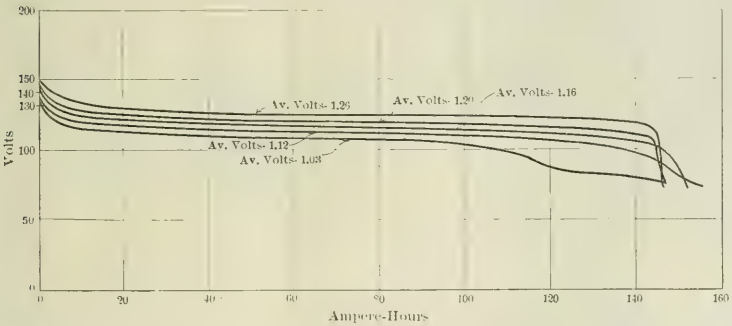


FIG. 1.—TEST OF LATEST TYPE OF EDISON BATTERY FOR DISCHARGE RATES BETWEEN 20 AND 100 AMPERES. WEIGHT OF COMPLETE CELL 12 LBS. 9 OZ.

Since the first announcement of the Edison nickel-iron battery in May, 1901, it has taken more than two years of elaborate and systematic work to bring the battery up to the conditions of chemical and mechanical perfection, in which Mr. Edison wanted to have it, before he would place it on the market. The first type of cell placed on the market is described in detail below, and profusely illustrated. Some very interesting results obtained with this type of cell by Prof. Hospitalier in Paris are also recorded below.

In the meanwhile, however, Mr. Edison has found that he can improve this type of cell, by using twice the amount of active material of nickel as in the former type of cell, while the amount of active material of iron is the same as before. He therefore uses always two nickel plates together, where in his former type of cell only one such plate was used. This improved type of cell will soon be placed on the market. The results of tests of this improved type are given in Fig. 1.

The weight of cell, complete with solution is 12 pounds 9 ounces. The total ampere hours for the various discharge rates change only slightly, while the average voltage is 1.26 for a discharge rate of 20 amperes; 1.20 volts for 40 amperes; 1.16 volts for 60 amperes; 1.12 volts for 80 amperes, and 1.03 volts for 100 amperes. For the 20-ampere rate, the watt hours are 140 ampere hours, multiplied by 1.26 average volts, i. e., 176.4 watt hours, hence 14.0 watt hours per pound of cell complete.

Of theoretical interest is the drop of the voltage curve at the end of discharge at the highest discharge rate (after 100 ampere hours at a discharge rate of 100 amperes). This drop is attributed by Mr. Edison to the concentration changes in the porous plates, which theoretically develop during discharge, the concentration in the pores of the active iron material decreasing, and the concentration in the pores of the active nickel material increasing, while the total concentration remains unchanged (E. F. Roeber, *Electrical World and Engineer*, vol. 37, page 1,105; *Transactions American Electrochemical Society*, vol. 1, page 195). But this drop is small, in agreement with the theory; and it is remarkable that such a drop of voltage is only with the highest discharge rate, and at the end of the run. This shows that the active mass in the Edison cell is of sufficient porosity to allow a quick exchange of electrolyte between the pores of the plates and the outside.

We regret that we cannot give the details of the preparation of the active material. We may simply mention that the greatest care is taken to employ absolutely pure materials, and that extensive special apparatus are used to purify all materials used in the cell.

One of the latest developments which should be of special interest to electrochemists, is that Mr. Edison has succeeded in making the containing iron jars of his battery by simple electrolytic deposition upon a mould. The process is very cheap, but requires some space; a detailed description of the method cannot be given on account of pending patent applications. Mr. Edison states that the task to make a durable and perfect iron jar by electrolytic deposition, seemed at first quite hopeless; "but you can solve all such problems, if you only keep on experimenting." The currogations in the sides of the zinc jar are made afterwards, and the iron jar is then nickel plated by the process described below.

MECHANICAL CONSTRUCTION OF THE EDISON STORAGE BATTERY.

In general appearance the cell combines elegance of design and finish, with a most solid and enduring mechanical construction. The entire cell is constructed of nickel-plated steel, except for a small amount of hard rubber used to insulate the plates from the sides, bottom and cover of the containing envelope and each adjacent plate from its neighbor.

Each individual steel piece employed in the construction of the cell is plated with a coat of nickel, which, by a special process, is fused to the steel. This process of Mr. Edison of plating steel with nickel is quite interesting in itself, and deserves some description. It may be applied to sheets or other forms which are subsequently drawn, stamped or pressed, or to articles which already have their ultimate shape. It is a pretty illustration of the fact that, even in the difficult case of nickel plating, any subsequent danger of pealing off may be avoided if the fundamental principle is taken into consideration that the alloying power of an electrolytic deposit with the coated metal underneath is a factor determining not only the strength with which the deposit adheres, but also the length of time the plated article will wear and resist corrosion (L. Kahlenberg, ELECTROCHEMICAL INDUSTRY, February, 1903, page 201). Mr. Edison plates the pieces of steel first in an ordinary nickel-plating bath, with a coating of nickel. By this method

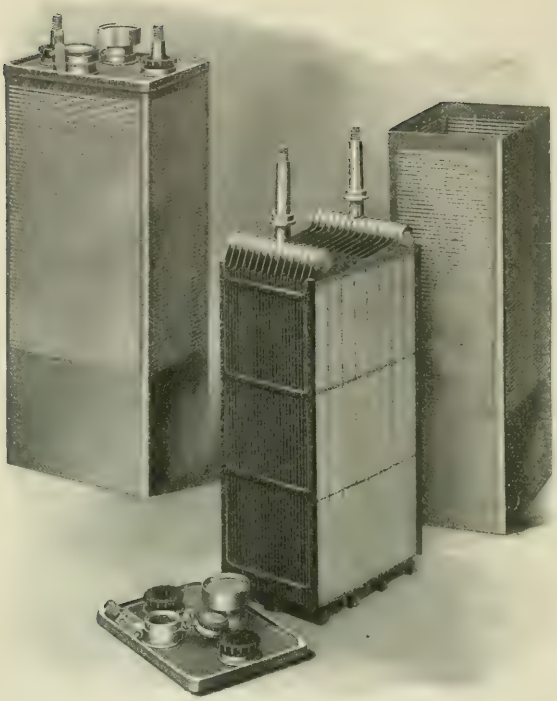


FIG 2.—COMPLETE CELL, CAN, PLATES ASSEMBLED AND COVER

FIG. 3.—TWO PARTS OF POCKET WITH LOOSE MATERIAL, ALSO LOADED POCKET

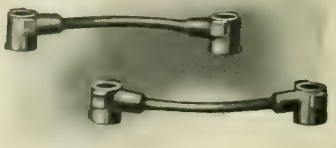


FIG. 4.—CELL CONNECTORS.

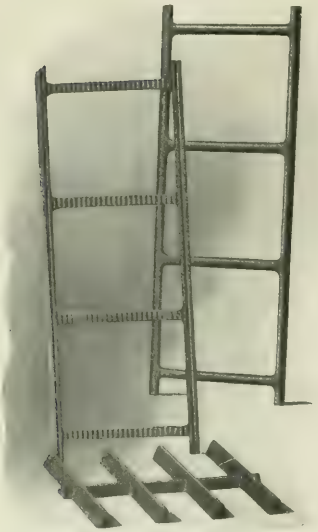


FIG. 5.—HARD RUBBER PLATE SEPARATORS AND CELL INSULATING PLATE.

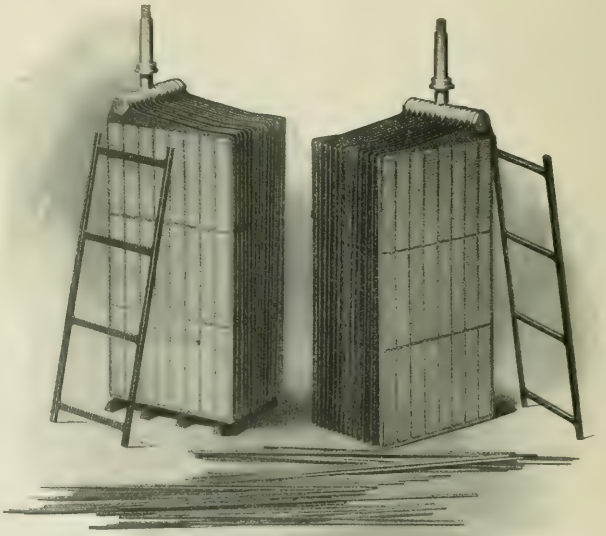


FIG. 6.—GROUP OF NICKEL AND IRON PLATES WITH PLATE AND PIN SEPARATORS

no alloying is produced between the nickel and the iron. Mr. Edison therefore accomplished this end artificially. The pieces are stacked together, and introduced into a cast-iron chamber or clay retort, in which a non-oxidizing atmosphere is produced by the passage of an inert gas, preferably hydrogen. While the current of hydrogen is passing, the nickel-plated steel articles are heated to a bright yellow heat in order to alloy the

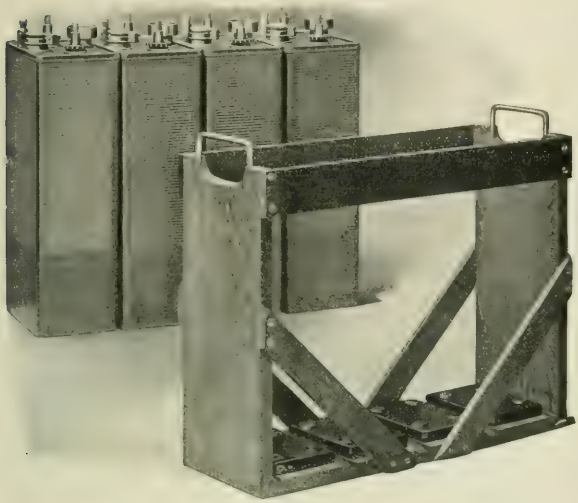


FIG. 7.—TRAY WITH FOUR CELLS IN BACKGROUND.

coat of nickel with the steel backing. The weld thus obtained is so good that the nickel film will not crack or flake off during the subsequent mechanical treatment to which the articles are subjected. The passage of hydrogen gas is continued until the temperature has dropped below the point of oxidation.

The active materials—consisting of specially-prepared oxides of nickel and iron—are held in very finely perforated cups or pockets, each pocket being made in two sections, one engaging within the other. Twenty-four of these pockets are placed in suitable rectangular openings in a thin nickel-plated steel grid, and the whole is subjected to a very strong pressure with the effect that the two sections of each pocket are firmly locked together and at the same time securely fastened in the grid. Each pocket almost becomes an integral part of the supporting grid. To this construction are due the mechanical strength and the lightness of the plate.

The type "D" cell of the Edison Storage Battery Company consists of 28 plates. Fourteen plates with an active material of nickel oxides are strung on to a connecting-rod, to which is fastened a suitable binding-post. Each plate is separated from the next by a spacing washer and the whole is held firmly in place by a nut which screws on the end of the connecting-rod. These 14 nickel plates are connected to the positive pole of the cell. Fourteen plates with an active material of iron oxides are assembled in identically the same manner, and are connected to the negative pole of the cell.

The positive and negative elements are so assembled that each iron plate has a nickel plate on either side of it, and each nickel plate an iron plate on either side of it, except in the case of the two end plates, one of which is a nickel, the other an iron plate. The outer surfaces of these two plates are in juxtaposition with two sheets of hard rubber that insulate the plates from contact with the sides of the containing jar.

The iron and nickel plates are prevented from coming in contact by means of hard rubber rods of a diamond shaped cross-section, a number of which are placed between each set of abutting nickel and iron plate surfaces.

The containing jar is made of corrugated sheet steel, the sides of which are prevented from coming in contact with the plates by the sheets of hard rubber mentioned above. The ends and bottom of the jar are protected from contact with the plates by means of specially designed pieces of hard rubber.

The cover is securely soldered to the jar, and is provided with two stuffing boxes, through which the binding posts extend, and with two other mountings, one, called the "separator," for separating the spray from the gases when the battery is charged, thus preventing loss of potash and causing the gases to be inodorous, the other, called the "filler," for filling in the electrolyte, and from time to time the distilled water.

The "filler" has a water-tight cover, which is held in place by a strong catch. Fastened to the cover is a small spring which causes it to fly open when the catch is released, and it cannot be closed again without some small pressure being exerted, nor will it stay closed unless the catch is securely fastened. This insures that the cover, when in place, shall always be water-tight, and also minimizes the chance of accidentally leaving the cover open, and the possible spilling of solution should the cells be severely agitated.

Each individual cell is held securely in place and free from contact with its neighbor by a little rubber device, which performs the double office of insulator between cells and lock to hold them firmly in position in the trays. Every cell rests upon a thin sheet of hard rubber, pressed into a suitable shape. This effectually insulates the cells from the bottom of the trays. In the bottom of each cell are four small indentations. These fit over conveniently arranged little wooden buttons protruding from the upper side of the tray bottom and prevent the cells from becoming displaced by sudden jolts or shocks, while affording a very rigid yet elastic support.

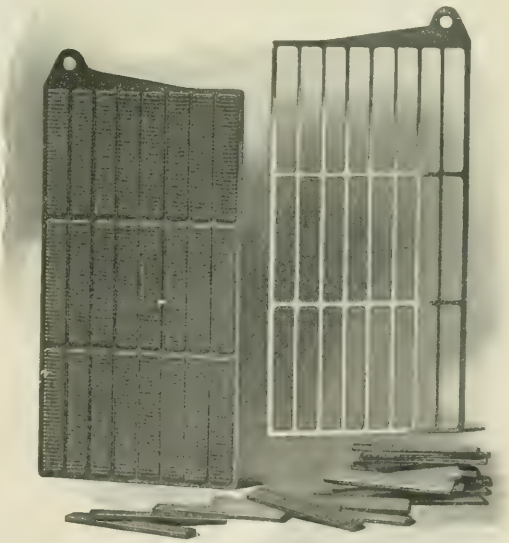


FIG. 8.—GRID AND GROUP OF POCKETS CONTAINING ACTIVE MATERIAL, TOGETHER WITH FINISHED PLATES.

The connection between cells is made by means of heavy, solid copper wire, well nickel-plated. On the ends of each copper connector are screwed specially shaped steel-lugs, which fit over the binding posts and make a taper joint connection with them, insuring a perfect electrical contact. A nut holds each lug securely in place, so as to make bad contact impossible, even though the battery may be subjected to extremely violent jolting in automobiles.

A socket-wrench for removing the nuts which hold down the connectors, and a specially designed jack for lifting the lugs from the binding posts when disconnecting the cells, are accessories belonging to the outfit of each battery; also a funnel for adding the distilled water, equipped with an indicator which shows when the right amount of solution has been put in the cell.

Tests of the Edison Storage Battery.

As was already noticed in these columns, the Edison battery has been tested by a number of authorities in the storage battery field. Results of such tests made in England by Mr. W. Hibbert are given in a recent paper of this gentleman, read before the (British) Institution of Electrical Engineers. The main results obtained by Mr. Hibbert were already given in our issue of October, 1903, on page 517. The additional information given in his Institution paper relates mainly to the durability of the battery, about which he speaks very favorably.

Of still greater interest appear to be the results of Prof. E. Hospitalier, the well-known French authority on storage batteries. From a paper published by him in a recent number of *L'Industrie Electrique*, the following information is gathered. The cell tested by Mr. Hospitalier was type 17D, the dimensions of which are as follows:

Length in the direction of plates....	13 cm.
Thickness	9. cm.
Height of jar	30.2 cm.
Height including binding posts	33.5 cm.

The weight of the cell was as follows:

Electrodes	5.925 kg.
Connections	0.060 kg.
Electrolyte	1.785 kg.
	7.770 kg.

Before the test was begun, in accordance with instructions from Mr. Dick, who represents the Edison Storage Battery Co. in Europe, the cell was charged with 30 amperes for 30 hours, and discharged with 30 amperes down to 0.75 volt; it was then charged with 60 amperes for 10 hours and discharged with 30 amperes. After that the real test began.

Prof. Hospitalier made a series of twenty-one charges and discharges, under the conditions given in table I., in the electric laboratory of the Ecole de Physique et de Chimie Industrielles of Paris.

For the charges No. 5 to 17, the rate of charging was only 10 amperes, on account of special conditions. Since a higher rate of charging is more suitable for this special type of battery, the results obtained by Prof. Hospitalier are slightly inferior to those obtained in the tests of Mr. Hibbert, and in the Laboratoire Central d'Electricité, but the differences are too small to affect the mean value, and the results obtained in the different tests may be considered as practically identical, if one takes into consideration that they were obtained under quite different conditions and with different cells.

In table 1 the letters have the following meaning:

E, electromotive force of the cell in volts before the beginning of the discharge.

I_d, constant current of discharge in amperes (discharge No. 12 was made with constant resistance).

U, mean potential difference at terminals of cell during discharge in volts.

T, the length of discharge, in hours and minutes.

Q, total output in ampere hours.

I_c, the current of the charge preceding the discharge in amperes (approximate value.)

While a series of twenty discharges is insufficient to enable one to estimate exactly the life and durability of an accumulator, yet, as Prof. Hospitalier points out, these discharges were probably made under conditions which would have put a lead accumulator out of service. Mr. Hospitalier calls special attention to the discharge No. 12, which was made with the cell nearly short-circuited, the initial current being 240 amperes, with 0.95 volt at the terminals. After forty minutes the current had dropped to 180 amperes, with 0.75 volt at the terminals. After this discharge at an excessive rate, the battery was charged with 10 amperes and gave 155 ampere hours in the thirteenth discharge. The fourteenth discharge was made twenty-four days after the charge. Compared with the preceding discharge, it indicates a loss in ampere-hour capacity of 10 per cent, that is less than ½ per cent per day, which is practically insignificant.

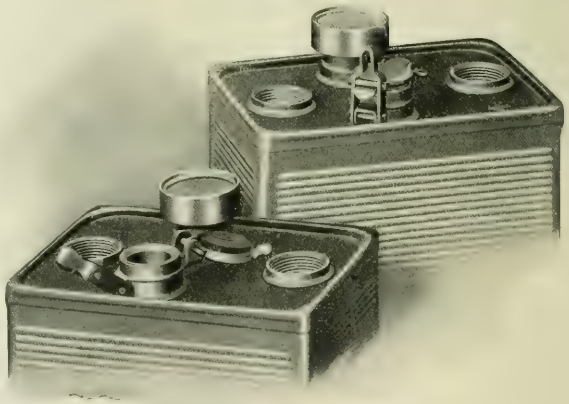


FIG. 9.—FILLER LID OPENED AND CLOSED.

After this discharge the battery was left standing discharged and was recharged on September 4. Discharge No. 15, of September 5, gave again the capacity of the thirteenth discharge, namely, 155 ampere hours.

The influence of a high charge rate is evident from the following discharges. After the seventeenth discharge the battery was short-circuited for seventeen hours, and then charged at a rate of 80 amperes. The eighteenth discharge at a rate of 50 amperes, gave 139 ampere hours, which indicated either an insufficient charge or a temporary loss in capacity. After a new charge the battery gave 154 ampere hours in the nineteenth discharge, and 160 ampere hours in the twentieth discharge, so that the short-circuit after the seventeenth discharge had not destroyed the capacity.

Similar results were obtained in the test of the Laboratoire Central d'Electricité. They show that it is possible to use rates of charging and discharging which would be excessive for the lead accumulator, while the Edison battery does not thereby deteriorate nor lose any appreciable amount of capacity.

A good indication of the life of an accumulator is the total energy furnished by it before it is put out of service divided by its weight. In the extensive competitive accumulator tests of the Automobile Club of France, made in 1899, this figure for the best lead accumulator (Fulmen) was 1.5 kw. hour per kg.

The Edison cell, when tested in the Laboratoire Central d'Electricité, was subjected to 125 discharges, and gave in the average 25 watt hours per kg. in a discharge, that is, in the

whole 3.1 kw. hours per kg., and at the end the capacity was not diminished. This is already more than twice the value of the best lead accumulator in the tests of the French Automobile Club mentioned above, but this does not yet indicate the limit.

Prof. Hospitalier then discusses the disadvantages of the Edison battery. The main disadvantage is that the useful potential difference is about 1.1 volt, while that of the lead accumulator is 1.9. This means that to get the same e. m. f., the number of Edison cells to the number of lead cells is 5 to 3, and in the same proportion the number of connections, etc., must be increased. The closed jar makes examination difficult and repairs expensive, but this inconvenience is compensated by the mechanical strength which renders examination and repairs less necessary. The price is probably higher for the same energy. For the same power, however, the comparison is in favor of the Edison cell if one takes into consideration the high rates which it can stand.

TABLE I.

Test No.	Date.	E In volts.	I_a In amperes.	U In volts	T In hours and minutes.	Q In ampere hours.	I_c In amperes.	Remarks.
1.	7 July	1.52	30	1.36	5 50	175	60	Charged July 6th.
2.	10 "	1.52	50	1.38	3 30	175	50	Charged July 9th.
3.	13 "	1.48	60	1.30	2 43	163	50	Charged July 12th.
4.	16 "	1.48	90	1.30	1 49	163.5	50	Charged July 15th.
5.	17 "	1.50	120	1.27	1 19	158	50	
6.	20 "	1.48	30	1.40	5 37	168.5	10	Charged with a small motor generator.
7.	21 "	1.52	50	1.41	3 18	165	10	
8.	22 "	1.50	90	1.40	1 46	159	10	
9.	23 "	1.52	120	1.30	1 17	154	10	
10.	25 "	1.46	30	1.36	5 07	153	10	
11.	27 "	1.44	30	1.34	5 15	157.5	10	
12.	28 "	1.47	240-180	0.95	0 40	133	10	Discharge with constant resistance.
13.	30 "	1.48	30	1.38	5 10	155	10	Charged again on July 31st.
14.	24 Aug.	1.34	30	1.24	4 43	141.5	10	After 24 days, left at rest after discharge.
15.	5 Sept.	1.48	30	1.35	5 10	155	10	Charged September 4th.
16.	9 "	1.46	30	1.42	5 20	160	10	
17.	6 Oct.	1.43	30	1.32	5 00	150	10	After discharge, short-circuited for 17 hours.
18.	12 "	1.45	30	1.28	4 38	139	80	
19.	13 "	1.52	50	1.34	3 05	154	80	
20.	15 "	1.46	50	1.32	3 12	160	80	
21.	20 "	1.44	120	1.10	1 15	150	10	

The watt-hour efficiency varies in the lead accumulator with the rate of charge and discharge. The lower this rate, the higher the efficiency. In the tests of the Automobile Club of France, the mean efficiency for the low rates adopted there was between 70 and 75 per cent. In the tests of the Edison cell in the Laboratoire Central d'Electricité—in which the discharge rate was varied, while the charge rate was maintained at 60 amperes—the efficiency varied between 43 and 57 per cent, that is, 50 per cent in the average. Prof. Hospitalier states, however, that this superiority of the lead cell is only apparent, since, in order to make a fair comparison, it would be necessary to have equal charge and discharge rates, but very rapid charges and discharges would be an impossibility with the lead accumulator.

The two most important characteristic factors of the automobile accumulator besides life and durability are power and energy per unit of weight. The higher these two factors, the better is the accumulator suited for automobile purposes. Mr. Hospitalier's curves, shown in Fig. 10, are very instructive in this respect. I., II. and III. refer to the Edison cell, I. being derived from the tests in the Laboratoire Central d'Electricité, II. from tests of Hibbert, and III. from the tests of Prof. Hospitalier; IV., V. and VI. refer to lead cells; IV. to the Contal accumulator, V. to the Fulmen accumulator, and VI. to the Blot-Fulmen accumulator.

These curves are characteristic and do not require long explanations. They show that for low discharge rates, like 3 or 4 watts per kg. of total weight, the output in watt hours per kg. is about the same for the Edison cell and the Fulmen cell, while that of the Contal cell is slightly higher. But all curves of the lead cell drop rapidly as soon as the discharge rate increases slightly, while the Edison cell curves are distinctly straight lines. For all discharge rates beyond 10 watts per kg. the lead cell is out of question altogether, while the output of the Edison cell decreases only slightly, so that at such a high discharge rate as 25 watts per kg. the energy output is still about 21 watt hours per kg. Prof. Hospitalier points out that this is one of the most valuable properties of the Edison cell,

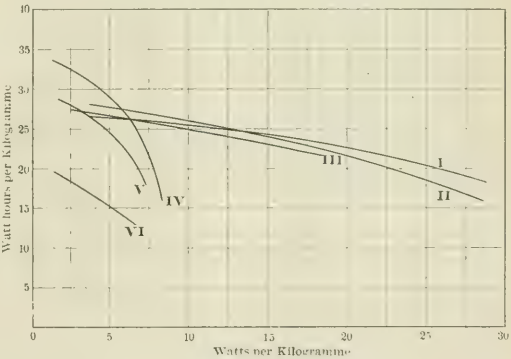


FIG. 10.—COMPARATIVE CURVES OF EDISON BATTERY (I., II., III.) AND LEAD ACCUMULATOR (IV., V., VI.).

and that with respect to this property it maintains a unique position among all storage batteries.

From a table of dimensions the following figures are derived, type X and type Y being two lead batteries of a large French manufacturer:

	Edison.	Type X.	Type Y.	Contal.
dm^3 per kw.	60	89.4	88.4	68.8
dm per kw. hour.	21.5	17.8	17.8	15.7
kg. per kw.	111	200	200	182
kg. per kw. hour.	40	40	50	36.4

These figures show that the Edison battery requires less space for the same power than the other accumulators, but a slightly larger space for the same energy.

Prof. Hospitalier concludes his article by expressing the opinion that the Edison battery represents an important and undeniable progress in electric automobilism. Its capacity of giving great power per unit of weight will permit to use lighter batteries in carriages which have to make only short trips per day, and thus to diminish the whole weight of the carriage. The possibility of rapid charges will also enable one to make longer trips, since a charge can be made in less than two hours without any deterioration of the battery. Should the discharged battery be left to itself for a few days without being charged again, it will be sufficient to recharge it twice, in order to bring it back to its initial capacity, and no harm will be done.

ACID RESISTING BRICKS AND RINGS FOR USE IN PACKING GLOVER AND GAY-LUSSAC TOWERS

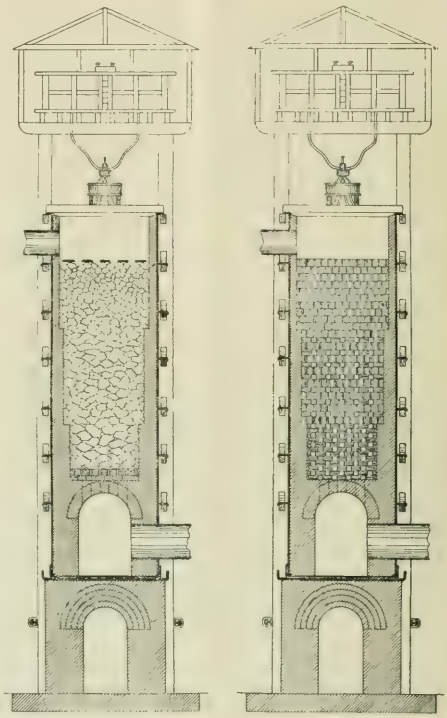
In sulphuric acid factories the Glover and Gay-Lussac towers are well known and highly important accessory apparatus. It was formerly supposed that coke was especially adapted as a packing for these towers on account of its porosity. Prof. G. Lunge, the well-known authority on chemical engineering, has pointed out long ago that this opinion is erroneous. In the first place, porous coke is worthless for a coke tower for which dense coke is indispensable. Secondly, the pores would at once be filled with the liquid, which thus would not come into contact with the gases passing outside. The assumption that coke is not acted upon by the gases or liquids within the tower, has also been proven conclusively to be erroneous. This without doubt accounts for some of the losses in the manufacture of sulphuric acid, when coke is used as a tower packing, and it also explains why the ordinary coke towers must be repacked every year.

In view of these facts, it is not surprising that coke as a tower packing has gradually been replaced by a chemical stoneware packing in form of acid bricks and rings. The accompanying illustrations show side by side a Glover tower with coke packing arranged in the best possible way (at the left side) and one with stoneware packing (at the right side), acid resisting bricks and rings being used in the latter case, as made by Messrs. Richard C. Remmey & Son, of Philadelphia, and the arrangement of these bricks and rings in the illustration shows that there is nothing left to chance. The acid by its downward flow is spread in thin films over the surface of the stoneware. As it drops from one layer to another it strikes on the flat upper surface of the lower layer and is scattered in the form of minute drops in all directions, and taking a new position passes down the succeeding layer in films which expose the greatest possible surface to the action of the ascending gases. The flow of the liquid is constantly interrupted, without in any way impeding the upward current of gases, thus having no pernicious effect upon the draught through the sulphur of pyrites burners.

These bricks and rings are made by Messrs. R. C. Remmey & Son, who control some of the best kinds of clay for this purpose, in sizes 4 to 6 in. in depth. The apertures through eight layers, view from above, show a very intricate lace work, which demonstrates the film-producing action of the method of packing. The upward current of gases is constantly being developed, having a tendency to cause the liquids to form these films upon the stoneware.

These bricks and rings are practically indestructible, and repacking of a tower becomes a very rare operation. Should a lower portion of a Glover tower become disturbed by the dust of fiercely driven fines burners, flushing the tower is an efficient remedy. A coke-packed tower cannot be so easily cleaned in this way.

The two standard sizes of rings made by R. C. Remmey & Son are an inside diameter of 4 and 2 in. respectively, with outside diameters of 6 in. and 4 in., a height of 4 in. and 3 in. and a weight of 72 and 21 ounces respectively. The smaller



GLOVER TOWER WITH COKE PACKING (LEFT HAND), AND STONEWARE PACKING (RIGHT HAND).

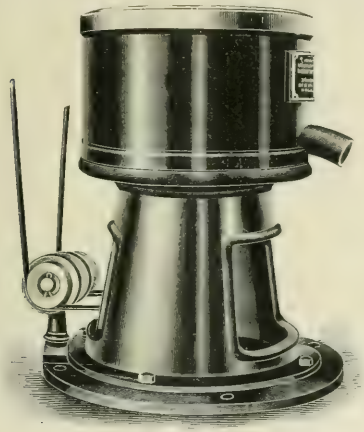
and lighter rings are placed nearest the top of the tower, in order to effect a finer sub-division of the descending acid and a greater surface exposure of films.

Recovery of Gold from Telluride Ores.—On this subject, which was dealt with in Dr. W. H. Walker's Electrochemical Society paper, a recent consular report from Germany gives the following notes: The discovery in recent times of extensive deposits of telluride-gold ores in Western Australia and the United States—notably at Cripple Creek, Col.—has given special importance to this subject, and it has been found on investigation that, so far as can be ascertained, the most improved and effective method known in Germany is one perfected and practiced by the London and Hamburg Gold Recovery Co., which has extensive reduction works at Hamburg, working the telluride-selenic ores from Western Australia. Of the process itself it has only been possible to ascertain that it is partially patented and partially held secret. What is known is that by this process telluride and selenic ores containing gold are pulverized and digested in a solution of cyanide of potash and cyanide of bromium, in proportions of 75 per cent of the former to 25 per cent of the latter. The method of precipitating the gold is kept secret, but it is certain that the process recovers 95 to 96 per cent of the gold contained in the ores, and this proportion is often as high as 97 or even 98 per cent.

CENTRIFUGAL MACHINE FOR CHEMICAL LABORATORIES AND FACTORIES.

Manufacturers of chemicals and of pharmaceutical preparations as well as research chemists in laboratories have felt for some time the need for an efficient apparatus which would rapidly and easily separate crystals or precipitates from their mother liquors. Such an operation may be accomplished in different ways, like decantation, free filtration, filtration under pressure and separation by centrifugal force. Decantation requires time, and will not yield dry solids. Free filtration is quite suitable as long as the amount of the solids is small; on the other hand, if the crystalline mass is considerable, a great amount of mother liquor or wash water remains in the crystals and the final drying takes much time. Filtration by vacuum under the filter is seldom satisfactory, and requires considerable time.

Filtration under pressure by means of a filter press is certainly an improvement on the precedent methods, yet is not practical in a laboratory. The main defects of this method are that the cakes obtained contain always a large percentage of moisture, and have to be dried; moreover, the crystals do not



CENTRIFUGAL MACHINE.

retain their perfect shape, on account of the grinding and pressure they are subjected to. The filtering cloths also wear rapidly, the cleaning of the filter press is a long and tedious operation. Finally, filter presses are expensive.

With the centrifugal separation these inconveniences are overcome. The separation is rapid, the crystals retain their perfect shape, and are almost dry; and may be completely dried in a very short time, and the emptying and cleaning of the machine is very simple, since the basket is simply lifted out of the machine, emptied of its contents, washed under a faucet, and the machine is ready for another operation.

The adjoining illustration shows the Cyclone Centrifugal Machine, made by Messrs. C. H. CHAVANT & Co., of Jersey City, N. J., which is intended to serve the purposes of, the chemist, as well as of the manufacturer. The revolving basket containing the mass to be separated, has a diameter of 10 inches, and is run by direct belt drive. They also make a smaller size for laboratory use, the diameter being 5 inches. The revolving basket is made of a special bronze alloy of great tensile strength, which will resist acids. In a few minutes any amount up to one pound of dry crystals is separated according to the density of the product. The speed, being about 4,000 revolutions per minute, is ample for an almost complete elimination of the liquids. The cylindrical tank collecting the liquors is enamelled in order to resist the acid liquors, and is provided with a spout for the discharge of the mother liquors or filtrate.

INDUSTRIAL NOTES

THE LOOMIS PETTIBONE GAS MACHINERY CO., manufacturers of gas apparatus and Crossley gas engines, with headquarters at New York City, have recently opened branch offices at Boston, Pittsburg and Chicago.

TRANSFORMER INSULATION.—Bulletin 5,003, of the FORT WAYNE ELECTRIC WORKS, contains a reprint of an illustrated paper by B. A. Wagner on transformer insulation and the use of the vacuum drying and substitution process.

HYDROGEN SULPHIDE.—The CHARLES GRAHAM CHEMICAL POTTERY WORKS, Brooklyn, N. Y., announce that they manufacture C. L. Parson's hydrogen sulphide generators, made from their special grade of chemical stoneware.

STEAM SPECIALTIES.—We have received from the WRIGHT MANUFACTURING CO., of Detroit, Mich., their illustrated catalogue of steam specialties, giving descriptions of improved safety water columns, steam traps, exhaust heads, etc.

ELECTROPLATING AND ELECTROTYPING DYNAMOS.—We have received from Mr. CHARLES J. BOGUE a very neatly illustrated pamphlet on his dynamos for electroplating, electrotyping and general electrolytic work, which were already described in detail on pages 431 and 516 of vol I. of this journal.

WATER PURIFICATION.—The AMERICAN STEEL & WIRE CO. have issued a pamphlet on water purification, with sulphate of iron, for domestic and commercial uses. The information given in the pamphlet is based on tests, made by Messrs. E. E. Irons and J. E. Campbell, at the waterworks of Quincy, Ill. The procedure is as follows: The sulphate of iron is dissolved in a tank of 3,600 gallons of water. Lime is dissolved in 2 tanks of 7,000 gallons each, sufficient water being used to exhaust CaO, and produces a clear solution. The water of the Mississippi River, from which the Quincy water works are supplied, is charged with the requisite quantity of sulphate of iron, while being pumped up from the river, and the lime is injected after the water has passed the pumps. Charged with both solutions, the water passes into the city sedimentation basin, where the solutions quickly draw from the water by precipitation and coagulation the animal, vegetable and foreign matter, leaving only a small percentage to be afterwards extracted by filtration. The quantity of sulphate of iron used at Quincy is about 1½ grains per gallon of water pumped from the river, which is usually extremely turbid, and the same quantity of lime is used. The result is stated to be a perfectly pure and palatable water, and the cost is said not to be higher than that of other means of purifying water. Sulphate of iron is one of the chemical products of the American Steel & Wire Co. The pamphlet gives many details of the process as operated at Quincy.

DIGEST OF U. S PATENTS

PRIOR TO JULY, 1902.

Compiled by Byrnes & Townsend, Patent Lawyers, National Union Building, Washington, D. C.

373,091. November 22, 1887. Heinrich F. D. Schwahn, Kansas City, Missouri.

Purifies and decomposes fats, such as oil, tallow and butter, by electrolyzing them at 100° C. The solid products settle.

The cell is a vertical, steam-jacketed cylinder carried by hollow trunnions which serve both as the axles of wheels running on a track and as steam pipes. The steam space is sub-divided by a perforated partition. Steam is also injected directly into the cell. One electrode is a vertical coil of wire which surrounds the other electrode, consisting of a rod carrying S-shaped arms.

448,541. March 17, 1891. Thomas Parker and Alfred E. Robinson, Wolverhampton, England.

Produces iodine by electrolyzing an acidified aqueous

solution of an iodide, as of sodium or potassium, in a diaphragm cell. The anode is of carbon or platinum; the cathode of iron. The cathode compartment preferably contains a caustic alkali solution. The iodine freed at the anode is drained, washed with cold water and dried in a current of warm air.

460,277. September 29, 1891. Joseph B. Gardner, Nyack, N. Y.

Regenerates the spent products of primary batteries. E. G. Employs a two-fluid battery with an anode of zinc in acidulated water and a cathode of carbon in a dilute solution of chromic acid produced by treating lead chromate with sulphuric acid. The spent battery solutions, either combined or singly, are treated with potassium or calcium carbonate, evaporated and ignited, giving zinc oxide and potassium chromate, which is dissolved out. This chromate is combined with the lead sulphate obtained in the first operation, reproducing the lead chromate.

466,720. January 5, 1892. Stanley C. C. Currie, Philadelphia, Pa.

Produces insoluble chlorides, as of lead, silver and mercury, by employing the desired metal as anode in a neutral electrolyte, preferably a solution of zinc chloride. Sodium chloride may be added to reduce the resistance. The mercury anode is held in a non-conducting cup. The electrolytic chlorine combines with the anode, giving the desired product, and the zinc is deposited on the cathode, which may be of zinc or lead. The zinc may be subsequently removed from the cathode by reversing the current.

501,578. July 18, 1893. Heinrich Pfanne, Rixdorf, near Berlin, Germany.

Produces varnish by electrolyzing an emulsion of purified linseed oil, water and sulphuric acid, for two or three hours. The cell is a cylindrical, closed vessel having a central, vertical shaft, carrying arms with wire-brush stirrers. The electrodes are two vertical, curved, zinc plates, at opposite sides of the stirrer.

511,450. December 26, 1893. Arthur Amos Noyes and Arthur Austin Clement, Boston, Mass.

Produces para-amido-phenol-sulphonic acid by electrolyzing a sulphuric acid solution of nitro-benzol. The anode, of platinum, is placed in a porous cup containing concentrated sulphuric acid. The porous cup and cathode, of iron, are placed in the nitro-benzol solution, preferably one part in four of concentrated sulphuric acid. Sufficient current is employed to heat the electrolyte to 90°-100° C. The electrolysis is continued until nitro-benzol is no longer precipitated on dilution with water. Water is then added to the product and the liquid filtered. The solid is washed with water and dissolved in caustic alkali. The sulphonic acid is precipitated from this solution by neutralizing with hydrochloric acid, washed with water and dried. It may be purified by redissolving in alkali and reprecipitating with acid.

541,597. June 25, 1895. J. D. Darling, Philadelphia, Pa.

Electrolyzes molten sodium or potassium nitrate and conveys the gaseous products to a Glover tower for the production of sulphuric acid. Cathode, a closed, cast-iron vessel, from the cover of which depend cast-iron anode-plates. The gases escape from a pipe having a glass section. When the evolved nitrogen peroxide is no longer seen in the glass tube, the current is switched to another cell. The molten residue in the vessel, mainly sodium monoxide, is run off and dissolved in water to produce caustic, the undecomposed nitrates being separated.

541,598. June 25, 1895. James D. Darling, Philadelphia, Pa.

Converts niter-cake and other acid salts into neutral salts, by placing a solution of the salt in the intermediate compartment of a cell having two transverse diaphragms. The end compartments contain a saturated solution of sodium chloride or other salt having the same base as the acid salt. An electric current is passed from lead anodes in the end compartments to a carbon cathode in the middle compartment and the sodium or other base neutralizes the acid salt.

553,593. January 28, 1896. Marius Otto and Albert Verley, Courbevoie, France.

Produces vanillin by electrolytic oxidation of solution of sodium isoeugenate. The anode and cathode compartments, provided with platinum electrodes, are connected by a relatively narrow tube to prevent mixing of the solutions; the anode compartment contains sodium isoeugenate solution, and the cathode compartment sodium hydrate. As the oxidation proceeds the isoeugenate is converted into vanillate, from which the vanillin may be separated by decomposition with oxalic or sulphuric acid. No data as to current.

572,512. December 8, 1896. Heinrich Albert, Biebrich, Germany.

Produces alkali phosphates in a diaphragm cell, the cathode compartment being filled with phosphoric acid solution, and the anode compartment with sodium chloride. On passage of the current, chlorine is liberated at the carbon anode, and the alkali neutralizes the phosphoric acid in the cathode compartment. In accordance with the quantity of the respective compounds may produce mono-, di-, or tri-basic phosphate in the cathode compartment.

579,317. March 23, 1897. Emile Joseph Constam and Arthur von Hansen, Zürich, Switzerland.

Percarbonates are produced in the anode compartment of a diaphragm cell, by electrolyzing, preferably at a temperature of 16° C., saturated solutions of the alkali carbonates. At this temperature the carbonate yields the ions MCO_3 and M, percarbonates of the formula $M_2C_2O_6$ being formed by union of two anions. The compound is an amorphous, bluish white salt, decomposing in water at ordinary temperatures with evolution of oxygen and carbon dioxide. It is therefore a powerful oxidizing and bleaching agent.

602,873. April 26, 1898. Joseph W. Richards and Charles W. Roepper, Bethlehem, Pa.

Insoluble sulphides are produced by the action of a hyposulphite solution on the corresponding metal anodes. As an example of the process sodium hyposulphite in 10 per cent solution is electrolyzed with cadmium electrodes, and yields directly the sulphide of cadmium or "cadmium-yellow." The reaction proceeds best at 75° C., and the color is brighter if 5 per cent of sodium chloride be added to the electrolyte. Refers also to antimony sulphide, which is best produced in a cold solution.

602,872. April 26, 1898. Joseph W. Richards and Charles W. Roepper, Bethlehem, Pa.

The process is substantially as above, save that an alternating current is employed. The special advantage is that the insoluble precipitate and the hydrogen are produced in alternating succession at the electrodes, and the hydrogen facilitates the loosening of the precipitate of metallic sulphide. No data as to frequency, etc.

630,612. August 8, 1899. Max LeBlanc, Frankfort-on-the-Main, and Hermann Reisenegger, Höchst-on-the-Main, Germany.

Method of producing chromic acid solutions and regenerating such solutions after use for oxidation. Chromium sulphate dissolved in suphuric acid is oxidized to chromic acid in the anode compartment of a diaphragm cell, and is then employed for any desired oxidation. If the reduced solution were returned directly to the anode compartment, the gradual increase in concentration of sulphuric acid would disturb the conditions, wherefore the reduced solution is brought first to the cathode compartment, wherein its sulphuric acid content is diminished, then introduced into the anode compartment for regeneration. In this manner the sulphuric acid concentration is maintained constant.

Electrochemical Industry

VOL. II. NEW YORK, FEBRUARY 1, 1904. NO. 2.

Electrochemical Industry

Published on the first of each month by the
ELECTROCHEMICAL PUBLISHING COMPANY,
[*Incorporated.*]
114-118 LIBERTY STREET, NEW YORK.

J. W. RICHARDS, PH. D. .....*President.*
E. F. ROEBER, PH. D. .....*Editor.*

Telephone Call: 7607 Cortlandt.

Subscription Price: $2 per year, postpaid to any part of the world. Single copies 25 cents.

ADVERTISING RATES GIVEN ON APPLICATION.

Copyrighted, 1904, by the Electrochemical Publishing Co.

Entered as Second-Class Matter, June, 1903, at the Post-Office at New York, N. Y., under the Act of Congress, March 3, 1879.

CONTENTS.

Editorial 45
On the Microstructure of Metals and Alloys. By Wm. Campbell.. 49
Electrometallurgy of Gold in South Africa..... 53
The Rare Elements. By Victor Lenher..... 61
Recent Improvements in Dry Cells of the Leclanche Type. By A. J. Marschall 63
Electrolytic Zinc. By Oskar Nagel 64
First Meeting of the New York Section of the American Electrochemical Society 64
Synopsis of Articles in Other Journals..... 65
Analysis of Current Electrochemical Patents. By Geo. P. Scholl.. 69
Correspondence: Contact Resistances and Current Leakages in an Electrolytic Copper Refinery. By B. Magnus..... 74
American Electrochemical Society Election. By J. W. Richards. 74
Electrochemical Society Badge. By W. A. McCoy..... 74
Current Notes 74
Book Reviews 75
Electrolytic Rectifier and Interrupter..... 76
Vacuum Drying Apparatus 77
Generators for Electroplating, Electrotyping and other Electrolytic Work 77
Personal 79
Industrial Notes 79
Digest of United States Patents, Prior to July, 1902. By Byrnes & Townsend 80

ELECTROMETALLURGY OF GOLD.

Electrolytic methods are used in metallurgy only at a comparatively late stage of a process, since mechanical treatment or smelting processes are generally necesssary to obtain a product which can be treated successfully or economically by an electrolytic method. This is indicated by the fact that so far as commercial metallurgy is concerned, electrolysis has achieved its greatest importance in the refining industries. In general it may be said that wherever a specially pure product is wanted, electrolysis is resorted to; and the same will be the case when a material cannot be treated by the ordinary metallurgical methods. A typical instance of the latter case is the metallurgy of gold. When considering the occurrence of gold in placers, and the ease with which the bulk of it can be recovered by crushing, and when further considering the crushing of quartz in the battery, and the ease with which the bulk of the fine gold particles can be recovered by amalgamation, it is quite natural that in the metallurgy of gold no refined chemical methods were resorted to for a long while. It was only after such gold-bearing materials as tailings and slimes were produced in enormous quantities that the necessity arose to recover the gold from the same, and the cyanide process was resorted to. In the development of this process South Africa has been prominent, especially in the development of electric precipitation, and for this reason we hope that the extended review of electrometallurgy of gold in South Africa from 1897 to 1899, which is published in this issue, and which we intend to follow up by other articles covering the more recent period, will be of interest to our readers.

We have just referred to electric precipitation, as distinguished from the method of precipitation by means of zinc shavings. While this distinction is quite clear from a practical point of view, it may not be superfluous to point out that both these methods are essentially an electrochemical phenomenon. The principal difference between the two methods is that in the case of electric precipitation we use an external source of current in order to pass a current through the electrolytic tanks, while in the precipitation by means of zinc shavings we have in the precipitation vat itself an immense number of minute galvanic couples or short-circuited galvanic cells, the energy of the electric current being here derived from the chemical energy of the zinc which is being dissolved. If we short-circuit a Daniell cell, copper is deposited on the cathode plate and zinc is dissolved from the anode. If we put zinc shavings, containing impurities of lead, etc., into a cyanide solution of gold, zinc is dissolved and gold is deposited onto the impure particles of lead which act as cathodes. If a chemically pure zinc plate is immersed in a sulphuric acid solution, no dissolution of zinc is observed; but if we use a commercial zinc

plate which contains impurities, the zinc dissolves readily and hydrogen is evolved at the impurities, which are in the zinc, and which now act as cathodes. The case of the precipitation of gold by zinc shavings is quite analogous, the main difference being that in this case we have at the cathode a deposition of gold, instead of an evolution of hydrogen. This explains why chemically pure zinc is unsuitable for use in the cyanide process, and why commercial zinc which contains impurities is better and why "couples," like Ehrmann's zinc-copper couple, or the Carter-Betty zinc-lead couple are still better.

The last-named couple appears to have aroused very great interest in 1898 in South Africa, as the discussion on the same, sketched in our article, proves. The apparently novel point in Betty's method is that he has not a zinc-lead couple pure and simple, but in combination with free cyanide. The action of the cyanide is quite evident. As was pointed out in our correspondence columns last year, by Mr. William Powell, in connection with gold plating, such addition is necessary to remove insoluble salts from the zinc surface, and the use of HCN would probably be even more effective. This fact is quite in agreement with observations made in other electrolytic processes. As Dr. J. W. Richards points out, in an article published in our January issue, the success of the Wohlwill process of gold refining, used in the Philadelphia mint, depends on the addition of free hydrochloric acid to gold chloride; when gold chloride alone is used as solution, only a fraction of the gold is dissolved from the anode, which the current should dissolve, but by acidulating strongly with hydrochloric acid the normal amount is dissolved. Another similar case is the electrolyte of lead-fluosilicate, containing an excess of fluosilicic acid, in the Betts process for refining lead.

While the precipitation of gold from zinc shavings is thus to be considered and explained as an electrochemical phenomenon, yet for practical reasons it is convenient and preferable to restrict the use of the term electric precipitation to the case in which an electric current is passed through the precipitation vats from an external source of current, as in the Siemens & Halske process. Mr. Charles Butters' description of how this process came to the front in connection with the extremely difficult slimes problem, and how this problem was successfully solved, will be read, we are sure, with the greatest interest. It is quite probable that in future zinc precipitation and electric precipitation will continue to be operated side by side, since the one method may be preferable under certain conditions, the other method under other conditions. This was the situation in South Africa in 1899, and it has not been essentially changed in the meantime. The important problem is to clearly define the conditions under which the one or the other process is more economical, and this problem can only be solved by experimenting and recording the results.

While all commercial applications of electrical methods in the metallurgy of gold are essentially based on first dissolving the gold in a cyanide solution, and afterwards precipitating it from the solution, we may refer here again to an entirely different method, which was described last year by Dr. W. H. Walker in an American Electrochemical Society paper. While experimenting with low-grade telluride ores from Cripple Creek, Dr. Walker wanted to determine the effect of chlorine and cyanogen at the moment of liberation at the anode, and for this purpose he had ore spread on a piece of platinum foil immersed in a solution of salt and potassium cyanide. The electrode intended to act as cathode was suspended from above. Through an error the feed wires were crossed and the platinum plate on which the ore rested, was made cathode. Almost immediately after turning on the current, gold was plated upon the platinum and a black cloud of tellurium was driven off. To prove that the anions Cl and CN played no part in this reaction, Dr. Walker substituted caustic soda as electrolyte and obtained identical results. It was thus proven that the gold was being recovered by cathodic reduction alone. The essential feature which distinguishes this reaction from the cyanide process is evident. In Dr. Walker's case there is direct reduction of gold from the ore, without a preliminary dissolution of the gold in the electrolyte.

We have already pointed out in these columns that Dr. Walker's method is thus analogous to Mr. Salom's process of reducing lead from galena. It makes no difference whether one wants to apply the usual terminology and speak of the action of nascent hydrogen. It is clear that we have to do in both cases with direct cathodic reduction. While endeavoring, however, to work out an industrial method for treating rebellious ores in this way, Dr. Walker experienced great difficulties. Quantitative runs were made on a rather rich sulpho-telluride ore from Cripple Creek, using 5 per cent caustic soda as electrolyte, and mercury for the cathode. By maintaining good agitation it was not difficult to obtain an extraction of 93 per cent of the assay value. The presence of finely-divided tellurium in the electrolyte seemed to cause excessive flowering of the mercury, and much trouble was experienced from this cause, This kind of trouble is, of course, absent in Salom's reduction of lead, since the hydrogen sulphide gas, developed at the cathode, goes off readily.

Dr. Walker points out the inherent difficulty of any such process for reducing gold from ore on a commercial scale. Every minute particle of mineral scattered through the relatively enormous quantity of gangue must be brought into direct contact with the cathode surface. But Dr. Walker's experiments are very valuable, since they may explain why some processes for treating tellurides of gold have promised well in the laboratory, but have failed on a commercial scale. In experiments on a test-tube scale, it is not difficult to bring a large percentage of the individual particles in direct contact with the cathode, and thus get a high extraction. But on a commercial scale the enormous quantity of worthless gangue, compared with the amount of gold particles, seems to offer very great difficulties. Moreover, former experimenters with rebellious ores, seem to have overlooked that they had to do with cathodic reduction.

THE MICROSTRUCTURE OF METALS AND ALLOYS.

In his interesting paper on this subject, published in the present issue, Dr. W. Campbell emphasizes a perfect truth, by saying that chemical composition is not everything, for, unless the microstructure be good, the best of materials will not make

the finished product anything but a very medium product. The importance of this fact has long been recognized by electrochemists, interested in electrolytic deposition of metals, and that our electrolytic copper refiners are fully aware of this truth and are studying the microstructure of their copper by metallographical methods, is evidenced by Mr. L. Addicks' paper, published in our December issue. What the buyers of copper wire are after, is not its chemical composition, but its properties, like electric conductivity and tensile strength; and while these properties depend on the chemical purity of the metal, yet they also depend on the treatment which the wire has undergone, since this treatment also determines the microstructure of the metal. As Mr. Addicks shows, we have in cast copper a conductivity resulting from the combined conductivities of the pure copper grains and the impure matrix and cement. When this is rolled, the structure is broken down and the complex shunt and series circuits are rearranged to better advantage. When hard-drawn, the molecular freedom is restrained and more work has to be done in the necessary oscillation of an atom in passing a charge on to its neighbor. In annealing, the wire is brought to a temperature at which the cement is softened, and all internal strain is equalized. In overheating and burning, crystalline growth is started and reverts the metal to the original condition.

It is thus a fact that the previous treatment determines the structure of a metal. Tempering and annealing produce distinct modifications of the structure. The state of a metal is therefore not solely determined by chemical composition and temperature, as might be concluded from the diagram for iron-carbon alloys given in Dr. Campbell's article (chemical composition and temperature being the two independent variables in this diagram). In other words this diagram cannot tell the whole story in the general case. We may assume with Duhem that this diagram really represents a simplified and ideal case, being true for a perfectly annealed system. Yet, it would be quite wrong to underestimate the value of the application of Bakhuis-Roozeboom's methods of chemical thermodynamics to the discussion of solid solutions in general, and of the special case of carburized iron. By means of our diagram, which represents the main result of the application of these methods, we were first enabled to get a simple and clear classification of the different states in which carburized iron may exist under varying percentages of carbon and varying temperature.

Metallography is a distinct science of its own, but as we have seen, the electrochemist, when specializing, is necessarily led to apply occasionally the methods of metallography, just as he is bound to use the methods of other sciences or arts in other cases. In other words, the more an electrochemist specializes, the more he will find it necessary not to be an electrochemist pure and simple, nor to restrict the methods at his disposal to those used in electrical and chemical engineering and science. The distinction made between the different sciences and arts is human work and wholly arbitrary. Nature, in every one of its phenomena is manifold, and the more we specialize in the investigation of natural phenomena, and the more we endeavor to consider every phenomenon from all possible points of view, the more we find it necessary to make use, not only of the method of one science or art, but also of those of all others. Thus, specialization is bound to lead to better appreciation of the fact that Nature is a unity which to understand we need all the different sciences together, and of the other fact that every engineering problem, to be completely solved, is to be considered not simply from the rather limited point of view of a single art; to conquer Nature for man, it needs the co-operation of all arts.

ELECTROLYTIC DEPOSITION OF ZINC.

The short article by Dr. O. Nagel, published in this issue, on the electrolytic deposition of zinc, is very suggestive. It is probably true that in experiments made in the past on the electrolytic deposition of metals on an industrial scale, the attention was restricted too much to the one metal under consideration in each case, and that often not enough attention was paid to the results of other investigators in analogous experiments with other metals. On the other hand, we believe that much more has already been accomplished in the commercial electrolytic deposition of metals than might appear to be the case from Dr. Nagel's article. We will mention only a few instances. Lead is obtained by Mr. Betts' electrolytic process (described in our issue of August last) in a perfectly solid and dense deposit, having very nearly the same structure as electrolytically-deposited copper. Solid nickel deposits of almost any desired thickness can be obtained by Mr. Browne's method (described in our issue of June last). Concerning iron, we may only mention the fact that Mr. Edison is now able to produce the containing jars of iron for his storage battery by electrolysis with perfectly satisfactory results. It will thus be seen that much has already been accomplished in producing, on a commercial scale, satisfactory deposits of metals which are higher in the tension series than hydrogen.

It would certainly be a praiseworthy undertaking to collect and classify all the results which have so far been obtained in this field, and to pay careful attention to the way in which the methods which have led to commercial success change from metal to metal. Then we would get a decisive answer to the question whether, as Dr. Nagel supposes, there is a parallelism between the sequence of the metals from copper to zinc, according to their tension, and the methods by which they can be technically produced by electrolysis. That the tension is one factor determining the electrolytic deposition, is self-evident. But it is another question whether the tension is such an important factor that metals of nearly equal tension can be deposited by nearly the same electrolytic method. This is a question which can only be settled by collecting the facts which are available, and by further experimenting. It seems quite possible that other factors like the characteristic structure of the metal play a more important part than its tension. Nevertheless, Dr. Nagel's suggestive proposition should be carefully considered by experimenters in the field of the deposition of metals, and efforts should be made to classify the results which have already been obtained. The peculiar and simple method by which Mr. Betts obtains the lead in a solid and dense structure—by means of a reducing action, practically accomplished by the addition of gelatine and glue—is certainly encouraging.

NOTICE TO OUR CORRESPONDENTS.

A package of our mail was lost in transit last month. If any of our correspondents addressed us on any subject, and have not heard from us, will they please communicate with us again, as the letter may have been among those lost.

Electrochemical Industry.

THE INTERNATIONAL ELECTRICAL CONGRESS OF ST. LOUIS.

September 12-17, 1904.

According to the present indications, the International Electrical Congress to be in session at St. Louis, September 12-17, 1904, will be one of the most successful that has yet been held, both with respect to the number of adhesions and to the value of the transactions.

Up to date about 3550 circular letters of invitations to join the Congress have been issued to persons or associations in North America. From these, 875 postal-card acceptances of membership have been received. About 350 similar circular letters of invitation have been recently sent to other countries. It is intended to issue in all about 5000 invitation circular letters in American, and about 6000 in foreign countries. It is expected that many persons will join the Congress, both in America and abroad, who do not expect to attend the sessions in St. Louis, in order to secure a copy of the Transactions, which will form one, and, perhaps, two, large octavo volumes. Collection of fees has commenced, and upon receipt of a fee the member will be forwarded a certificate of membership, a reproduction of which is shown herewith. The certificate is 8½ inches by 11 inches in size (21.5 cms. × 28 cms.) and printed on heavy paper, and is signed by the president, secretary and treasurer.

Recently 280 special letters of invitation have been issued on behalf of the committee of organization to prominent electricians and electrical engineers, signed by the president and the general secretary of the committee, requesting papers for the Congress in the various sections. Of these, 146 have been sent to foreign authors, and 134 to American authors. There has not been time to receive replies from more than a few foreign authors, but twenty-one acceptances have, up to date, been received from abroad, and forty-six acceptances from North America. Sixty-seven papers are thus already promised for the Congress, and the number is steadily increasing. A considerable number of invitations to contribute papers have yet to be issued. It is hoped that the Congress will convene with a full programme in each section, and that at least half of the papers may be from foreign countries. According to the plans of the committee, papers for the Congress programme are specially invited, but papers voluntarily offered will be submitted to the officers of the sections to which the papers belong, and may be included in the programme by invitation at their request, if the subjects are desirable, and if the schedule alloted to each section will permit, it being the desire of the section officers to secure and offer the best possible programme and presentation.

Among those foreign electrochemists who have already accepted the invitation to present papers are Prof. W. Borchers, Aachen; Dr. F. Dolezalek, Berlin; Dr. Hans Goldschmidt, Essen; Prof. F. Haber, Karlsruhe, and Mr. J. Swinburne, London.

Petitions from the Congress committee of organization, and from the president of the American Institute of Electrical Engineers, have been filed with the Department of State at Washington, through the Department of Commerce and Labor, and the National Bureau of Standards, urging that the various foreign governments should be invited to appoint official delegates to the Congress. The lists of such delegates to be invited is in accordance with the lists allotted to the various countries at the Paris Congress of 1900, and the Chicago Congress of 1893. Including the United States, the lists comprise fifty-six official delegates. Information has been received that these petitions have been granted, and that the State Department, on the 17th of December, 1903, instructed the diplomatic officers of the United States abroad to extend an invitation to foreign countries to be represented at the Congress by delegates.

Arrangements are being made with a view to perfecting plans of co-operation between the Congress and electrical societies and associations in various parts of the world. Invitations have already been extended to the Congress members to visit places of electrical interest on the journey to or from St. Louis.

The committee of organization of the Congress consists of Elihu Thomson, president; A. E. Kennelly, general secretary; W. D. Weaver, treasurer; Bion J. Arnold, vice-president and chairman of the executive committee; C. F. Scott, Dr. S. W. Stratton, Prof. H. S. Carhart and Prof. W. E. Goldsbrough, vice-presidents.

A list of the officers of the various sections has already been published on page 560 of our issue of December, 1903. All communications should be addressed to the general secretary, Dr. A. E. Kennelly, Harvard University, Cambridge, Mass.

THE ELECTRIC CLUB JOURNAL.

The Electric Club of Pittsburg, Pa., which was organized on March 19, 1902, and consists principally of apprentices and engineers of the Westinghouse Electric & Manufacturing Co., announces that it is now to enter a new field by issuing a monthly publication of its own, under the title, *The Electric Club Journal*. The first issue will appear on February 1.

ELECTROMETALLURGY OF IRON.

We are informed that a commission has been appointed by the Canadian government for the purpose of investigating the different electric furnace methods in use in various iron and steel plants in Europe. This committee consists of the following gentlemen: Dr. Eugene Haanel, Supt. of Mines in Canada; Mr. C. E. Brown, electrical engineer, and an English steel expert. Dr. Haanel and Mr. Brown sailed from New York on January 23 for Europe. The commission will visit France, Italy and Sweden, and it is likely that it will be four months or more before the commission returns to the Dominion.

ACID-PROOF RUBBER GOODS.

The following notes on acid-proof rubber goods are taken from a recent consular report. According to Dr. C. O. Weber, pure vulcanized rubber is very little acted upon by acids; the less pure the smaller the capability of the rubber to absorb aqueous liquids. It is well known that Para rubber on prolonged immersion in water will eventually be found to have absorbed from 24 to 28 per cent of water. On testing different brands of rubber, it is found that they exhibit great differences in their capability of absorbing water, and that this variation very closely follows the percentage of resinous matter contained in the various brands. This should not, however, be taken to amount to a recommendation to use, in the manufacture of acid-proof goods, resinous, low-class rubbers only. This would in so far be a mistake, as the rubber substance proper of the low-class rubbers is itself much more readily affected by the above-named acids than the high-class rubbers, notably Para. But this observation of the decreased capability of low-grade rubbers to absorb water clearly indicates the line to be followed in the production of acid-proof goods. It will, indeed, be found that mixings of Para with resins show a very much decreased capability of water absorption, but there are, as a matter of fact, several substances which prove far more efficient in this respect than the resins, and which at the same time are less objectionable for compounding purposes than the latter. These substances are paraffin wax, ceresin, mixtures of paraffin wax and heavy mineral oils, and, better still, the products obtainable by treating paraffin wax with sulphur.

ON THE MICROSTRUCTURE OF METALS AND ALLOYS.

By William Campbell.

Since the application of the microscope to the study of metals and alloys, our knowledge of their constitution has made rapid progress.

When a metal cools down from the liquid state and reaches its freezing point, it begins to crystallize out in the form of dendrites or skeleton crystals. The more rapidly it passes its temperature of solidification, the more rapid will be its crystallization, and the smaller will be its resulting structure. This dendritic structure is common to all metals, though each has its characteristic form. The crystals of lead in the Pattinson process, those of bismuth in a crust of that metal, the stars of antimony ingots are too well known to need more than mention here.

Fig. 1, magnified 35 diameters, shows the surface structure of aluminium cast in the form of a thin sheet on a cold stone

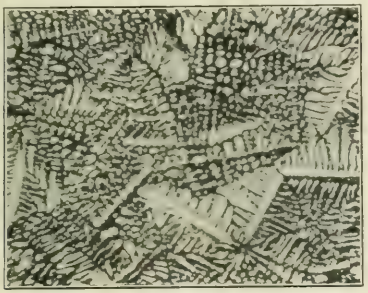


FIG. 1.—SURFACE OF CAST ALUMINIUM.

slab. It consists of dendrites with two main axes at right angles, from each of which grow out club-like secondaries.

Dendrites grow more freely in impure than in pure metals, for the presence of a more fusible mother-liquor allows of freer growth. In a very pure metal the surface is usually smooth, but etching reveals the granular crystallization of which dendrites are merely the framework.

Even electrolytically deposited metals may be crystalline. Fig. 2, magnified 35 diameters, shows a section of electro-copper fresh from the vat. It has been polished and etched with nitric acid. The difference in orientation of the grains or crystals is marked. Fig. 3, magnified 20 diameters, shows some crystals of electro-silver. Their crystalline habit is marked. On the other hand, electro-nickel and electro-iron have an onion-like structure due to concentric growth, and so far no crystals have been observed.

The crystalline structure of metals has been carefully worked out by Ewing and Rosenhain[1], who also observed the effects of strain, and of annealing. Within the elastic limit no change is noticed. As soon as deformation takes place, slip-lines are seen in the grains or crystals. They are more or less straight and parallel in each crystal, but are differently oriented in different crystals. Those which first appear are more or less normal to the line of strain, but as the strain increases systems lying in other directions appear. In some metals the slipping apparently takes the form of twinning, like plagioclase felspar.

When the strain is severe, as, for instance, in rolling or hammering, the large crystallization due to initial cooling, is broken down, and a much finer structure results, which is still truly crystalline.

Annealing causes a rearrangement and crystals grow, in some cases to a size larger than the original before hammering, etc. This change in the solid occurs at temperatures far below the melting point. In fact, in the case of lead, tin, etc., it takes place very slowly at normal temperatures.[2]

The effect of strain on the crystalline structure of lead has recently formed the subject of research by Humphrey.[3]

Iron and Steel.[4]

Professor Howe has written a very excellent book on iron, steel and other alloys,[4] which brings our knowledge of the constitution of iron and steel thoroughly up to date.

Iron and carbon form a simple series of alloys above 1100° C., falling into group I. of LeChatelier's classification by cooling curves.[5] In other words, the freezing-point curve consists of two inclined branches meeting at the eutectic point. In the curve, branch A B corresponds to the falling out of solution or freezing out of the crystals of iron. Branch D B corresponds to the separating out of graphite, while the horizontal branch a B C corresponds to the solidification of the mother-liquor, or eutectic of iron and graphite. The B D graphite is kish.

Fig. 9, magnified 35 diameters, shows an alloy occurring between a and B. It consists of dendrites of iron, surrounded by a matrix consisting of alternate laminæ of iron and graphite. The dendrites began to crystallize out when the molten alloy reached the temperature of the curve A B. They continued to grow and enrich the mother-liquor (with respect to carbon) till the later had a composition of B at a temperature just above 1100° C. The mother-liquor then solidified as alternate laminæ of iron and graphite.

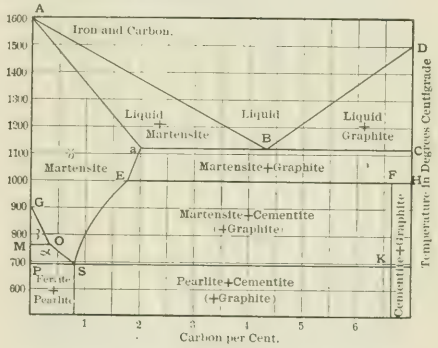


DIAGRAM OF ALLOYS OF IRON AND CARBON.

As Rooseboom has shown, the line Aa gives the composition of the dendrites as they fall out of solution. Iron becomes saturated with carbon at a, or about 2 per cent. In other words, the concentration of the solid solution of carbon in iron at 1100° C. is about 2 per cent.

This solid solution is called martensite. As the temperature falls to 1000° C. the solid solution is reduced to 1.8 per cent, and more graphite separates out.

Now, in the region a C H E we have martensite and graphite in equilibrium, but as the temperature falls below E H, or 1000° C., this is no longer so. A reaction takes place.

Martensite + graphite = cementite, and Fe_3C is formed. Thus, below 1000° C. martensite and cementite are in equilibrium. As a matter of fact, the reaction between martensite and graphite is so slow and so difficult that it rarely goes more than a little way. The reverse or the splitting up of cementite into graphite and martensite readily takes place, when a white iron is heated to above 1000° C., though Tiemann has shown that the presence of some silicon is necessary.

Now, suppose we have a liquid of the composition a to B,

[1]Phil. Trans., Royal Society, London, 193, p. 353; 195, p. 279.

[2]Mineral Industry, XI., 1903, p. 662

[3]Phil. Trans., Royal Society, London, 200, p. 225.

[4]Sauveur and Whiting, Boston, 1903.

[5]See J. Franklin Institute, 1902. "On Structure of Metals and Alloys."

and it cools past A B, dendrites of iron fall out. But if the cooling be so fast that it reaches the region where martensite and graphite are no longer in equilibrium, before it solidifies, then we have martensite and cementite formed.

Fig. 10 × 35, shows a section of washed metal. It contains dendrites of iron as before, set in a matrix. But this matrix consists of alternate laminæ of iron and cementite (Fe_3C). The carbon runs 3.5 per cent. On heating this up to above 1000° C., we should have graphite formed.

Thus, gray irons have solidified at a temperature in which graphite and martensite were in equilibrium, and as these two react with difficulty we continue to have graphite. On the other hand white cast irons possess a matrix which solidified for the most part at a temperature where martensite and cementite were in equilibrium, and so we have no graphite present.

And now we must say a few words about those alloys of our series lying between G and E per cent C., or low, medium and high carbon steels. Below Aa we have a uniform solid solution of, say, 1.8 per cent carbon in iron. This solid solution acts just like a liquid solution when it cools, and we have solids crystallizing out. Hence, we get a second V-shaped curve, G O S E, consisting of two inclined branches, G O S and S E meeting in the point S (or 0.8 per cent carbon) and the horizontal branch P S K.

G O S corresponds to the falling out of solution of the constituent ferrite or pure iron; E S corresponds to the falling out of cementite or Fe_3C, while P S K corresponds to the change of the mother-solid or *eutectoid* from a solid solution of 0.8 per cent C. into alternate laminæ of pure iron or ferrite and cementite (Fe_3C). This eutectoid is pearlite, and the change takes place at the recalescence point, just below 700° C.

Now, a steel with less than 0.80 or S per cent carbon would, when slowly cooled, consist of ferrite and pearlite. The ferrite would have separated out along the curve G O S. A steel with 0.80 per cent carbon, consists of pearlite alone, which forms at the temperature P S K; while a steel with more than 0.80 carbon consists of pearlite and cementite (Fe_3C), which separated out along S E.

Now, iron has three forms, α, β and γ. In pure iron α exists up to the temperature M, about 760° C. β exists between M and G (900° C.), while γ exists at temperatures

FIG. 2. ELECTROLYTIC COPPER, POLISHED AND EDGED.

above 900° C. In steel, iron is in γ form when it exists above G O S in martensite. In the area G O M it occurs as β, while below M O S it is in the α form. Thus, the line G O represents the separation of β iron from the solid solution martensite, the line O S represents the separation of α iron from martensite, while the line M O denotes the change of β into α iron with fall of temperature.

Figs. 4 to 8 represent the series of steels found in class G to E per cent carbon. Fig. 4 × 110 diameters, shows a steel containing 0.035 per cent C. It consists of large grains of ferrite with patches of a dark material, which, under a higher magnification, is seen to be pearlite. The steel was heated to 1100° C. and slowly cooled.

Fig. 5 × 110 diameters, contains 0.22 per cent C. The ferrite areas have decreased and the pearlite has increased with the increase in carbon. This steel was heated to 1100° C. and slowly cooled.

Fig. 6 × 110 diameters, shows a steel containing 0.37 per cent C., heated to 1200° C. and slowly cooled. The pearlite areas are now continuous and contain the patches of ferrite.

Fig. 7 × 35 diameters, shows a steel with 0.5 per cent carbon. The ferrite is in the form of veins and cell walls round the pearlite areas. The shape of these grains of pearlite is due to the fact that they are pseudomorphs of martensite. This steel was heated to over 1300° C., and the grains are coarse. The size of grain varies as the temperature to which the steel

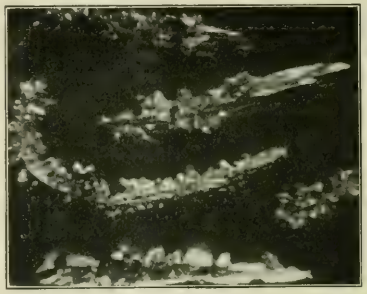


FIG. 3. CRYSTALS OF ELECTROLYTIC SILVER.

has been heated above the critical point, P S K. With further increase in carbon the ferrite disappears at 0.8 per cent C, and we have the steel consisting of pearlite alone.

Above this point we have steels containing an excess of cementite (Fe_3C), which separates out along the line E S, while the residual martensite changes to pearlite on reaching the temperature S K as before.

Fig. 8 × 110 diameters, shows a steel containing 1.17 per cent C heated to 1200° C. and slowly cooled. It consists of white bands and threads of cementite set in a matrix of pearlite, just as below 0.8 per cent C. we had ferrite in pearlite.

Returning now to our cast-iron, in Fig. 9 the dendrites of martensite are white, because they have been only lightly etched. On deeper etching they are seen to be built up of two constituents—pearlite and an excess of cementite. What happened was as follows. The dendrites of martensite on passing the temperature E H become supersaturated with cementite, which separates out from the mother-solid, whose composition follows the line S E as the temperature falls till at just under 700° C. it has the composition of S (0.8 per cent C). At this temperature, the recalescence point, the residual martensite changes over to pearlite. The same holds good for the white iron in Fig. 10.

From the above we see that low, medium, high carbon steel and gray or white cast-iron form one unbroken series, and the difference between white and gray iron is merely one of equilibrium at the solidification point of the mother-liquor, whether graphite (gray) or cementite (white) is in equilibrium with the martensite.

In steel the structure is of very great importance. All steels in the martensitic state, i. e., those which have been quenched from temperatures above the line P S K are hard. There is still great discussion as to whether hardening is due to the existence of γ iron or the retention of martensite by quenching. Medium carbon steel quenched from within the area P S O G is hard, apparently because the cementite is retained

in solution with the ferrite, as the solid solution martensite, and not as a free constituent of the eutectoid pearlite.

On the other hand, it is said that pure iron, when retained in the γ state is hard. Perhaps both the allotropists and the carbonists are right, and hardening is due both to γ iron and to carbon or cementite in solid solution.

The size of structure is also important, for the strength depends to a great degree on the size of grain. The size of grain is that of the martensite, and the higher the temperature above P S K, to which the steel is heated, the coarser the grain, till we reach A a C, when melting begins.

If steel is worked, as, for instance, by rolling or hammering, crystallization only takes place after this has ceased. Hence, we have had much research on finishing temperatures, and such processes as the Kennedy-Morrison[6].

Much work[7] has been done recently on the structure of iron and steel, and many very important facts have been brought to light. The identity of sorbite as the transition of martensite into pearlite is established[8].

Stead and Richards[9] in a paper on sorbitic steel rails give a simple method for the production of sorbite in steel. The usual method has been to reheat and oil-harden, or to reheat to dull red after quenching in water. They quench the heads of rails (after sawing to length) to below Ar1, and then allow the residual heat in the rails to temper them. They find that a normal rail of 37 tons tenacity has a strength of 45 tons after being made sorbitic, without any loss in contraction of area.

They point out that in all structural steels which have to undergo friction, percussion or vibration, the pearlite ought to be replaced by sorbite.

Stansfield[10] points out that the burnt structure of very much

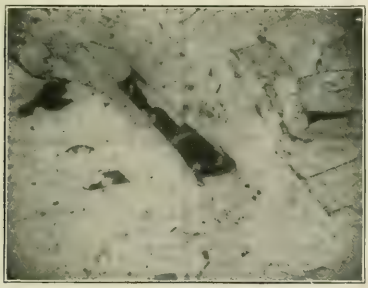


FIG. 4.—0.035 PER CENT C. × 110. FERRITE AND PEARLITE.

overheated steel is caused by the partial melting due to heating the steel to temperatures above Aa. He recognizes the following stages:

I. Overheating (below the point of incipient fusion).
II. Partial melting or burning.
(a) Merely producing segregation of carbon in the joints.
(b) Accompanied with liquation and producing flaws.
(c) Further liquation and oxidation in the flaws.

I. Steel that has been merely overheated can be completely restored by reheating just above its highest recalescence point and allowing to cool.

II. Steel in the stage (a) can be restored by suitable annealing; in stage (b) forging would also be needed; and in stage (c) it would be restored with great difficulty, if at all.

The heat treatment of steel under conditions of steel works practice has been studied by Campion[11]. He finds that steel containing 0.20 carbon has three critical points,

Ar3	Ar2	Ar1
798° C.	730° C.	670° C.

[6]Mineral Industry, IX., Iron Age, Dec. 20, 1900.
[7]Mineral Industry, XI., 1903, p. 663 et seq.
[8]J. Iron and Steel Institute, 1902, I., p. 120 et seq. and discussion.
[9]Journal Iron and Steel Inst., 1903, Sept.
[10]Journal Iron and Steel Inst., 1903, II.
[11]Journal Iron and Steel Inst., 1903, I., p. 378.

Small rolled sections can be heated to a maximum temperature of 850° C. without serious injury. Slow-cooling from 800° C., or more, to Ar1 tends to produce brittleness, however. In larger sections 800° C. ought to be the maximum temperature above which the metal ought not to be heated if it has to stand sudden shock. In the case of large forged bars 700° to 850 C. are the limits of temperature at which such material should be treated. Between 500° and 650° C. brittleness is produced, especially when slow cooling follows.

Steel containing 0.30 to 0.40 carbon shows two critical points:

Ar3.2	Ar1
725° C.	680° C.

and when in small, rolled sections, it is improved for resisting shock after heating to 650° to 800° C. The rate of cooling

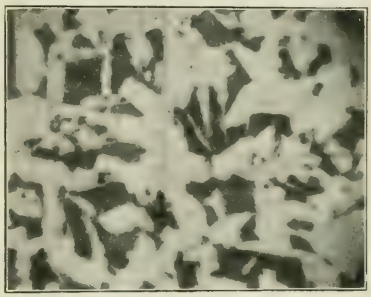


FIG. 5.—0.22 PER CENT C. × 110. FERRITE AND PEARLITE.

does not affect the result. No brittleness results from heating between 500° and 600° C. For large rolled bars the best temperature is 700° to 800° C. A brittleness develops at 900° and higher. Slow cooling is apparently not very harmful. In the case of forged bars, 6 inches diameter, the best temperature is between 700° and 760° C.

Steel containing 0.50 to 0.60 carbon has one critical point, Ar3.2.1 at 673° C. Small rolled bars give the best results after heating to 700° to 800° C., with slow or rapid cooling. The same temperature answers for larger rolled bars, but for forged material the temperature ought to be slightly lower.

Steel containing 0.60 to 0.70 carbon has Ar3.2.1 at 670° C. Small rolled bars gave best bending tests after heating to 600°

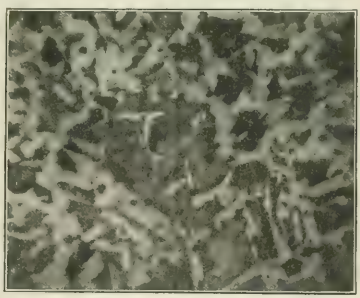


FIG. 6.—0.37 PER CENT C. × 110. FERRITE AND PEARLITE.

to 700° C. Thicker bars at 720° C. Rate of cooling is of small importance. Six-inch forged bars require a temperature of 700° to 760° C., while heating large bars of this carbon content to over 850° C. produces brittleness.

Alloy and special steels are now receiving great attention. Léon Guillet has carefully worked out the structure[12] of nickel

[12]Bull. de la Soc. d'Enc., May 31, 1903.

steels, while Colby is working out their physical properties, etc.

Tungsten steel is being studied by Hadfield[12] and others, while chrome and other rarer steels are being experimented with.

One of the great effects of alloying other metals with steel is in general to lower the critical points.

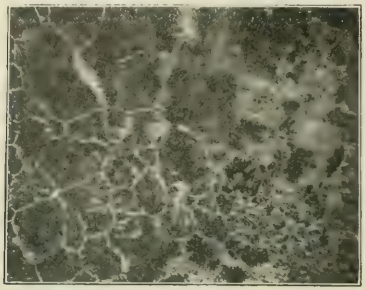


FIG. 7.—0.5 PER CENT C. × 35. VEINS AND WALLS OF FERRITE ROUND PEARLITE AREAS

The influence of sulphur and manganese on steel has been studied by Arnold and Waterhouse[14], who find that sulphide of iron is very injurious to steel, while sulphide of manganese is comparatively harmless. Iron sulphide is relatively fusible, has a high coefficient of contraction, and tends to form cell walls round the ferrite. On the other hand, sulphide of manganese is much less fusible, segregates while the iron is at a high temperature, and collects in the form of rough globules, seldom of meshes.

Manganese retards the segregation of iron and hardenite, and the so-called pearlite of a normally cooled manganese steel is really a mixture of granular pearlite and unsegregated ferrite. Very slow cooling allows the complete separation of the ferrite in a manganiferous steel, but such slow cooling injures the steel by lowering the maximum load and the reduction of area.

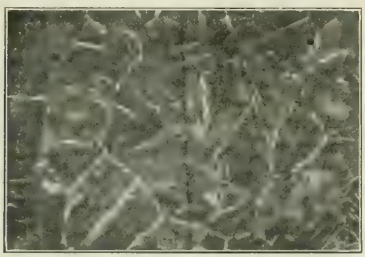


FIG. 8.—1.17 PER CENT C. 110. CEMENTITE AND PEARLITE

Le Chatelier and Ziegler[15] have done some very interesting research upon sulphide of iron, its properties and its conditions in iron. They found that commercial sulphide of iron ($FeS_{0.8}$) contained three constituents:

1. Some yellow grains constituting the bulk of the sample. They are sulphide of iron.

2. Brilliant parts having a metallic lustre much more pronounced than the sulphide, and a white color very similar to that of iron. This constituent is metallic iron.

3. Finally, between the yellow grains, occurs a eutectic of sulphide and oxide of iron.

The sulphide melts at 950° C. On the other hand, an alloy of manganese and 0.14 per cent sulphur shows dendrites of sulphide set in a matrix of manganese. Therefore, sulphide of manganese crystallizes out before the manganese and therefore is less fusible than iron.

Boudouard[16] has determined the points of allotropic changes of iron and its alloys by the measurement of the variations in the electric resistance. His work shows that the phenomena of the electric resistance of iron and its alloys in functions of the temperature are perfectly reversible outside the limits of temperature in which the allotropic changes occur. In the region of the critical points, the difference between the heating and the cooling curves of carbon steels is greater the higher the percentage of carbon. Steels containing chromium, manganese, tungsten, etc., show distinctive features similar to those of steels with more than one per cent carbon.

In the case of carbon steels the electric resistance increases with the carbon content. The addition of chromium and of tungsten increases the resistance sensibly in the ratio of 1 to 2. This ratio of increase is not maintained at high temperatures, but the resistance becomes about equal to that of carbon steels. Manganese at ordinary temperatures increases the resistance two or three times, while nickel produces an even greater resistance. However, in both cases the ratio of increase falls off at higher temperatures.

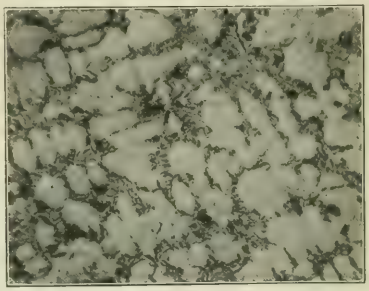


FIG. 9.—GRAY CAST IRON × 35. IRON CRYSTALS IN GRAPHITE GROUND MASS.

Alloys.

A remarkably good piece of work on the alloys of copper and tin has been published by Heycock and Neville[17]. Their photographs remind one of Osmond's on steel. In a diagram they explain the constitution of the whole series of alloys, using Rooseboom's theory of solid solutions.

There is no doubt that in the case of the bronzes, brasses, aluminium copper alloys, and others, that we have to deal with changes in the solid. For instance, between 80 and 90 per cent copper in the Cu-Al series, the alloys set as a whole in the form of solid solutions directly akin to martensite. At a low temperature $AlCu_3$, or AlCu (?) separate out, whichever happens to be in excess, just as did ferrite or cementite in steel. Finally, the mother-solid changes from a solid solution into a eutectoid of alternate laminæ of the two compounds.

In the case of copper and Cu_4Sn the case is rather more complicated, for part of the copper separates out from the liquid alloy, but the change in the solid is the same[18].

Boudouard has worked out the constitution of the alloys of magnesium with aluminium[19] cadmium[20] and copper[21].

[12] Iron and Steel Inst., Sept., 1903.
[14] Journal Iron and Steel Institute, 1903., I., p. 136.
[15] Bull. de la Soc. d'Enc., Sept., 1902.
[16] Journal Iron and Steel Institute, 1903, I., 299.
[17] Phil. Trans., Royal Society, 202, p. 1-69.
[18] Proc. Inst. Mech. Engineers, London, 1901. Appendix to Alloys Research Committee Report.
[19] Bull. de la Soc. d'Enc., Dec., 1901.
[20] Bull. de la Soc. d'Enc., Aug., 1902.
[21] Bull. de la Soc. d'Enc., Aug., 1903. See also Comptes Rendus, 1901 and 1902.

He finds that $AlMg_2$, AlMg, and Al_4Mg can be distinguished. The first two are shown in the freezing-point curves. In the case of the Cu-Mg alloys, he has isolated $CuMg_2$, CuMg and Cu_2Mg, the freezing-point curve giving maxima for these alloys.

The Société d'Encouragement pour l'Industrie Nationale has published a volume entitled "Contributions à l'Etude des Alliages." It contains the researches undertaken by the committee on alloys of the Society. It has two papers of great interest, viz., "Microscopic Study of Metallic Alloys," by Charpy and Osmond's great paper on steel.

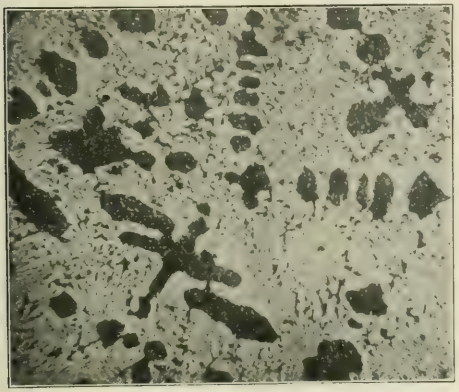


FIG. 10. WASHED METAL. (WHITE CAST IRON, 3.5 PER CENT C.) IRON CRYSTALS IN A GROUND MASS OF CEMENTITE AND IRON.

In the near future we are to have the last report of the Alloys Research Committee, Mechanical Engineers London, which will finish up the late Sir William Roberts-Austen's work.

Stead and Osmond's book on iron and steel from the point of view of microstructure, etc., will be out very shortly. If it equals their past work, it will be unrivalled, for they are unquestionably two of the foremost men on the subject to-day. It is due to such men that we are beginning to be impressed with the fact that chemical composition is not everything, for, unless our structure be good, the best of materials will not make our finished product anything but a very medium article.

ELECTROMETALLURGY OF GOLD IN SOUTH AFRICA—1897 TO 1899.

The Transvaal is the classical country of the metallurgy of gold. The extremely interesting volume II. of the Proceedings of the *Chemical and Metallurgical Society of South Africa*, which has just been published, covering the time from February, 1897, to September, 1899, contains an enormous amount of information on gold metallurgy. In the following notes we give abstracts of some papers which we believe to be of special interest to our readers. As an introduction we give a part of Mr. CHARLES BUTTERS' presidential address.

METTALLURGY OF GOLD.

Mr. Butters gave a concise review of the development of the metallurgy of gold. The occurence of gold in placers, and the ease with which the bulk of it was recovered by washing; later, the crushing of quartz in the battery and the winning of the fine particles by the beautiful process of amalgamation, were all so simple that for many years there was really no metallurgy of gold. Gold miners became educated only in the system of collecting free gold for the reason that the bulk of the production of gold was, and is, by amalgamation, and only such ores as give up their gold freely by simply crushing, were sought for and worked to any extent. The process of collecting such gold was one of concentration by means of amalgamation, and as the concentration was carried further another product was the result, being the concentrated pyrites of the value of from three to five ounces of gold per ton. Now, to obtain this gold, or a higher percentage of it than could be extracted by further crushing, certain and many processes were studied. This was most practically worked out by Plattner with his chlorination process, and up to some fifteen years ago amalgamation and chlorination were almost the only practicable means in use for winning gold in the gold mines of the world.

The idea of rehandling the whole of the products after concentration had been resorted to came almost in direct opposition to the recognized methods of winning any metal. In the recovery of all metals successive concentration is the method of procedure, and even to-day the metallurgists of Germany are very much averse to agreeing to the fact that it is not the best way of finally treating all the stuff which has been crushed. It has always been more or less known that large losses of gold take place in the pulp by concentration, but as these sands and slimes were usually allowed to be washed away in rivers the loss went unnoticed until, in the Transvaal, on account of its topographical condition, the slimes and sands were necessarily retained or conserved in dams. These accumulations being assayed and valued, showed plainly that something must be done to obtain their contained value. Concentration having reached its limits, another form of concentration was resorted to by the chemists in the shape of the introduction of the solution methods. Of these methods brought forward by various chemists, those of dissolving in cyanide and chlorine, are the only ones in effective use on the Witwatersrand to-day.

There has been a great deal of study given to the use of chlorine as a dissolving agent, but its use is very limited in comparison with that very easily handled solvent, cyanide, so that the author is prepared to state that cyanide is slowly but surely displacing chlorine on the Witwatersrand for all purposes. He has no doubt that upon these fields eventually the use of chlorine will be discontinued; and, having been among the first to be connected with the introduction of the chlorination process in South Africa, he has rather jealously guarded the interests of chlorine as a solvent. He admits now that, given equal preparation of material for the use of the solvent, the same percentage of solution of precious metal in the materials treated can be obtained as well with cyanide as with chlorine. And with the application of recent methods for the recovery of the gold from these solutions, as high a percentage of extraction can be obtained by the cyanide as with the chlorination process.

Continuing the work of recovery by solutions, we get first in dissolving the gold in the solution a new material of less value per ton than it was in the material to be treated. Generally speaking, it may be said that for the sand treated, it takes from a ton and a half of solution to dissolve the gold, while in slimes, from four to six tons of solution is used to dissolve and wash out the gold, and it is in connection with the solution, varying in value from ½ dwt. up to 10 dwts., that the metallurgical chemist is presented with the last problem in concentration which he must apply to his operations—viz., the concentration of gold from the liquid. For this operation we have at present only two processes acting successfully—that of zinc precipitation and that of electric precipitation on lead foil or shavings. The chemicals and substances that could be used as solvents in the work of dissolving the gold from the material are not more varied than the number of precipitation processes which may be employed for its ultimate recovery or concentration from the liquid used as a carrier; but, of all solvents, cyanide has proved itself the most generally useful and serviceable.

Zinc-Copper Couple for Gold Precipitation from Cyanides.

In a paper on this subject Mr. L. Ehrmann points out that the zinc process has been in great favor on account of its simplicity, and very successful in general practice; but there are cases where it has proved too slow, or the percentage of gold extracted from the solution too low. This is the reason why, principally with poor solutions, the electrolytic process is used, when the simpler method of zinc boxes seems ineffective. There is no doubt that electrolytic processes for extraction of metals from solutions are, scientifically speaking, the best, as they can be regulated; but they require more care and technical knowledge than the ordinary zinc process. An electrolytic process can be made more simple, if electrolysis of the solution is produced in the zinc boxes, by contact of two different metals, instead of being produced by an external source of electricity. The question of elevation of temperature of the solution, so as to facilitate the chemical reactions to make them more complete and rapid, is also of extreme importance.

The author has made experiments in which he investigated the effect of an increase in temperature and compared the effect of zinc with that of a zinc-copper couple. In the first case zinc shavings were used in the ordinary way, the zinc being commercial zinc bought in Johannesburg (not chemically pure zinc; this is important, since chemically pure zinc is known to have a very small precipitating effect); in the second case he used zinc shavings more or less coated with a very thin film of copper. The zinc coated with copper he calls a zinc-copper couple. The zinc is, of course, only partially coated.

His experiments show that a zinc-copper couple gives better results than zinc shavings alone, and that an increase of temperature has a very beneficial effect, since fresh zinc and a zinc-copper couple precipitate as much gold by hot treatment (at 175° F.) in two hours, as by cold treatment in twenty-four hours. He suggests to use the zinc-copper couple instead of zinc shavings, and to heat the solution to 175° F.

In the discussion Mr. C. Butters remarked that in practice, where there are a thousand tons of liquid handled in a day, it is practically impossible to raise the temperature to 175° F.; neither would it be economical, since coal is very expensive in the Transvaal. Several of the engineers who took part in the discussion remarked that they had not observed any difference in the precipitation in summer and in winter, while Mr. G. T. M. McBride stated that he had noticed he obtained a little better precipitation in summer than in winter, but the difference was very slight. (Some very interesting data on this point are given below under the heading, Influence of temperature on the cyanide process.) Mr. J. R. Williams has found the more impure the zinc, the better it is for the purpose of precipitation. He thinks the use of zinc-copper couple to be superfluous; he has not met with a single case of bad precipitation which cannot be successfully overcome by the addition of a little lead salt of any form (like lead acetate) which is soluble in caustic alkali or in cyanide of potassium. To explain the action of the lead salt, he offers two hypotheses: The one that lead is precipitated in a spongy form on the zinc, thus forming a very good couple, the other being based on the supposition of catalytic action.

Bi-Products from Cyanide Works.

From a paper by Mr. Charles Butters, the following notes on bi-products from cyanide works are taken. The bi-products that are obtained from the cyanide works are very much less in the case of fresh unoxidized ores than from acid or partly oxidized ores. Where the ores crushed have been exposed to atmospheric influences, and are partly weathered, the products of incomplete decomposition of the iron compounds always introduce a series of complications in the solution and precipitation of the gold that increases the amount of bi-products, whether the gold so dissolved is precipitated by chemical or electrical agency. In the case of the unweathered pyritic ore, or of perfectly oxidized ore, a solution is obtained comparatively free of iron salts, but in the case of a partially oxidized ore the ferrous and ferric salts produced form, with cyanide and alkali, ferro-cyanides and ferrous and ferric hydrates. These diminish the efficiency, more especially of the chemical precipitating agency, and also increase the amount of sludge obtained from the electrical precipitation boxes.

In the case of these acid ores a comparatively large amount of lime is needed, which, going into solution in the shape of hydrate, carbonate, and sulphate of lime, crystallizes out in the zinc box, and in the electrical precipitating box upon almost everything that it comes in contact with, more or less destroying the precipitating surfaces. This is a serious difficulty in the treatment of acid slimes. The surfaces of the lead cathode are almost completely covered after a few weeks by these comparatively insoluble lime salts, which gradually slip off the lead surfaces. By carrying down gold they tend to enrich the precipitates in the bottom of the boxes, as well as the floating precipitates which pass through the boxes and out into the sump.

In zinc precipitation everything that accumulates in the box in the way of slime is taken as the main clean-up. The particles which flow away from the box in mechanical suspension in the form of insoluble complex cyanides and hydrates, clayey matter, insoluble humus which has been precipitated from humic acid, and, in fact, any flocculent precipitates that may float through the box, will always carry gold along with them, which may be partly deposited in the sump. Hence, one might properly say the only bi-products produced directly from the zinc precipitation boxes, outside of the products resulting from the treatment of zinc slimes, are the precipitates obtained from either the settlement of the precipitated liquors, or the precipitate obtained by filtration of all the liquids after passing through the zinc box.

Under ordinary conditions, in a well-conducted cyanide works treating fresh ores, filtration of the precipitated solutions merely to obtain the floating matter from the zinc boxes would not pay, but where acid ores are treated, the precipitated sludge obtained from the sumps is of sufficient importance to warrant its careful collection. This precipitate varies in value from 1 up to 20 ounces to the ton. Precipitates so obtained from the Simmer and Jack cyanide works, where fresh pyritic ores have been treated, assayed 2 ounces 18 dwts. During the precipitation of rich solutions, running from 5 ounces to 8 ounces to the ton, flocculent precipitates assaying 14 ounces per ton, and composed of zinc cyanide and zinc ferro cyanide, insoluble in the dilute liquor used, were carried over into the sumps. A skimming taken from the top of the treated tank partly mixed with exhausted residue, gave an assay of 16 dwts. per ton, due mainly to finely-divided precipitated gold, which had been pumped back. Black skimmings of organic matter, resulting in the same way from the filtering through sand of precipitated liquors, gave an assay of 5 dwts. per ton. It is worth the attention of cyanide managers to see that the sumps are regularly cleaned of sludge, which may be dried by pouring into a small enclosure or dam made of tailings in the open air. After two or three weeks this material is dry enough to sample and assay, and in nearly every case will be found rich enough to sell to the smelting works. The gold in precipitates so obtained is not easily soluble in cyanide solutions, unless special preparation is given to their proper oxidation, either by means of preliminary roasting, or long-continued exposure to aeration and agitation with cyanide solution in an agitating vat.

In the Siemens & Halske precipitation boxes the main clean-up is obtained from the melting of the lead cathodes. Whatever else is obtained from the box in the shape of gold, is termed gold from bi-products. The sources of these bi-products are the insoluble compounds of iron and cyanogen. The iron of

the anode oxidizes, forming ferrous hydrate, which partly unites with the cyanide in the solution forming ferrocyanide, from which Prussian blue is derived, and partly undergoes further oxidation to ferric hydrate. Portions of these precipitates settle in the bottoms of the boxes, and a portion floats through them into the sump, where they become by degrees oxidized to the ferric state. This precipitate also adheres to and saturates the sacking which covers the iron plate; when, after long usage, this sacking becomes rotten it is removed and burnt, and the anodes are likewise carefully scaled of oxide. The value of the Prussian blue, of the ashes resulting from the burning of the sacks, and of the scalings of the plates, vary with the care and regularity with which the process has been carried on.

In a sand plant, where all the solutions come filtered clear to the boxes the Prussian blue may be cleaned up for sale every two months, and may contain from 5 to 50 ounces to the ton. The products from the sacks and the plates, which is obtained every one or two years, may have about the same average value as the Prussian blue. The value of these bi-products has averaged, so far, at the Worcester, which is the oldest Siemens & Halske sand plant, about 25 ounces for scalings in 1895, and 21 ounces for scalings in 1896, 21 ounces for Prussian blue in 1895, and 9 ounces for Prussian blue in 1896.

In a slime plant the difficulty of obtaining an absolutely clear liquid for precipitation introduces a certain amount of ore slime which becomes mixed with the Prussian blue, thereby increasing the quantity and decreasing the value of this product. With fresh slimes a clearer liquid and less mud is introduced into the precipitation boxes than with acid slimes, while with mud from imperfect settlements, precipitated lime salts, and the formation of insoluble sulphates and hydrates and complex cyanides, any precipitation process, no matter how perfect, is very much handicapped.

To prevent this state of affairs in the precipitation boxes, the author constructs sand filters to clarify the liquid before precipitation. When a sand and slimes plant are worked together, as at the Bonanza, a large proportion of the solution decanted off from the slimes, can be clarified by passing through the sand vats as a wash. The precipitates which form in the boxes themselves do not have nearly so bad an effect as the introduction of a small amount of finely divided silica or clay. While there may be over 1 ounce to the ton of finely-suspended siliceous slime in the liquid flowing through the box, still this small quantity coats both the anode and cathode with a fine film of non-conducting material, thus preventing the gold from adhering firmly to the cathode, as well as raising the voltage in the box. Hence, the clarification of the solutions, whether from fresh or accumulated slimes, will tend to reduce the amount of bi-products, which must be sold and increase the percentage of gold directly obtained by the melting of the lead strips.

The melting of the Siemens & Halske strips is generally done in a small reverberatory furnace, about 5 feet by 2 feet 6 inches. If this lead is fairly clean and free from siliceous mud and iron salts, a quick, clean melting takes place, and at the end of the operation, a little powdered coal may be spread over the surface of the oxidized bath and the temperature raised to as high a point as possible; afterwards the furnace is allowed to cool down and the lead tapped into moulds. In addition to the clean lead obtained from this melting, which may run from 5 per cent up to 10 per cent in gold, there is obtained a clean liquid slag, which is mostly litharge, or, in the case of dirty lead strips the temperature obtained is not sufficient to slag this, and a pulverulent residue is left in the furnace which is known as "skimmings."

Generally, where it is necessary to make more than one melting for a clean-up, all the skimmings resulting from previous meltings are put into the furnace, and the furnace is brought up to as high a temperature as possible, and the skimmings are sweated of their remaining lead contents. When every drop of lead has been drained from them that can be obtained, the hot skimmings are raked out and allowed to cool. These skimmings are then ground in a Chilian edge-roller mill and screened through a screen of about eight holes to the linear inch, from which two bi-products are obtained, known as "coarse metallics" and "ground skimmings."

The coarse metallics are melted in a pot and yield one or two bars of lead. The lead bars obtained from the melting furnace are then remelted in an iron melting pot, carefully skimmed, and poured into moulds. The skimmings obtained from this melting pot are added to the first lot of the skimmings obtained from the reverberatory furnace. All the lead, whether obtained directly as bars from the reverberatory furnace or from melting the coarse metallics is considered lead bullion, and only the skimmings are known as "bi-products," for the reason that the skimmings must be remelted in a pan furnace before their contents are obtained as lead bullion. Under careful treatment, the amount of gold obtained in the skimmings may be reduced to under 1 per cent. The cupellation of this bullion produces another set of bi-products, amounting to about ¼ per cent, which are known as the "refinery bi-products."

Electrolytic Precipitation of Gold.

Of the greatest interest are the following remarks of Mr. Charles Butters, taken from his presidential valedictory address on the solution of the "slimes problem," relating to the economic treatment of slimes produced by battery crushing. It is, perhaps, superflous to state that Mr. Butters has been most intimately connected with the development of the practical methods representing the solution of this problem. While the final step of precipitating the gold by electrolysis will certainly be of the greatest interest to our readers, yet some brief remarks on the preliminary treatment of the slimes seem here to be in order.

The working of the slimes consists essentially in the coagulation of the slimes in battery water by means of lime, their concentration by spitzkasten, and final settlement in continuous overflow vats or pits. Slimes represent a substance which cannot be leached or through which the solution will not percolate, but which must be washed by decantation. The result is that we have in this case a very large volume of much diluted solution to deal with, and at the same time the slimes contain as moisture nearly their own weight of solution. In order, therefore, that slimes may be economically treated, it is necessary to use a very dilute solution of cyanide, so that too much cyanide may not be lost with the residues when discharged, and that too much may not be decomposed during treatment. In this case one has to work with dilute solutions containing from 0.01 to 0.001 per cent of cyanide, and from 6 to 24 grains of gold per ton. The author speaks very favorably of the system introduced by J. R. Williams, known as "natural settlement" in very large and very deep tanks, together with the system of "double washing," devised in order to reduce the amount of solution passing through the precipitating boxes.

The solution of the gold requires, as well known, the presence of oxygen. This fact renders the treatment of old accumulated slimes much more difficult than that of fresh slimes, for the reason that the former contain a considerable amount of reducing agents. To supply the oxygen required for the dissolving of the gold several methods are possible. A. Caldecott has first introduced a method of introducing atmospheric air through a perforated pipe in the bottom of the vat containing the charge of pulp, while it undergoes agitation. After preliminary oxidation of the pulp has taken place, in order to lessen cyanide consumption, cyanide is added and aeration continues. It was thereby found that the gold dissolved as readily by this method as in the case of fresh slimes. Another method introduced by J. R. Williams is to transfer

the pulp from one vat to another by means of a centrifugal pump. In the passage of the pulp through the pump and pipes more or less air is drawn in through pump and pipe joints and glands, and a certain amount of oxygen is absorbed by the pulp, while the same is undergoing the most perfect agitation in its passage through the centrifugal pump, and afterwards through the pipes. When the stream from the outlet of the pipe falls upon the surface of the pulp remaining in the vat a large amount of air is likewise entangled and carried below the surface by the falling stream, thus causing the very perfect aeration to take place. This method has been found very effective.

The author expresses the opinion that in the future tanks with large diameter, and with great depths will be used without agitators, and the solution of the gold will be done by pumping from one tank to another through a centrifugal pump. The deeper the tank the less moisture or gold-bearing liquid will remain with the pulp, and the fewer times it will be necessary to repump the slime pulp from one vat to another, and the less power will be required per ton of slimes treated. Since the final step of the electrolytic precipitation of the gold is of special interest to our readers, we quote Mr. Butters' remarks on this subject nearly in full, as follows.

Precipitations of metals from solutions present many curious and interesting problems, and one of these is that with the same reagents it is very much more difficult to produce perfect precipitation from a very dilute solution than from a concentrated solution. There are certain chemical and physical laws in connection with this question which are probably not very well understood. For instance, in precipitating gold from a solution of its chloride by means of ferrous sulphate, a fairly rich solution containing 1 to 4 ounces of gold to the ton admits of a very perfect precipitation, if sufficient time is given for settlement, more especially when there are few other metallic salts in solution. A similar solution, but containing only 1 or 2 dwts. to the ton, allows of very imperfect precipitation by ferrous sulphate. This is only one of many illustrations that could be brought forward in connection with chemical precipitation, wherein the results obtained differ widely from what might be expected.

In electrolytic precipitation we have a different set of laws governing the electrodeposition of metals from those which operate in chemical precipitation. In the course of his experiments on the precipitation of dilute cyanide liquors the author tried many methods of precipitating solutions containing 6 grains to 12 grains of gold per ton, but failed completely with such dilute liquor; whereas the same methods acted perfectly on 5 dwts. or 10 dwts. solution. With a dilution of gold down to 6 dwts. per ton, which is about one part in 100,000, it would be natural to think if it was one part in 100,000, or one part in a million, or one part in ten millions, there would not be a very great difference in the resistance of such very minute proportions of dissolved gold to precipitation, whether by electromotive, or by chemical reaction; but the difference between the action of a liquid containing 6 dwts. per ton and one carrying 6 grains per ton is most marked, both in chemical precipitation and in electrolytic deposition.

In general he has found that he could effect the precipitation of the gold in these dilute solutions best, and most economically, by means of electrolysis. He has found that he is more independent in this method of dilution of the gold, and that varying chemical constituents do not have to be looked after quite so closely. It is independent of the amount of cyanide contained in the liquor, and precipitation takes place whether the solution is alkaline or acid.

The principal points in electrolytic precipitation that it is desirable to study, are the amount of current per square foot of anode and cathode, and the time the current is exerted, taken in conjunction with the value of the solution. One of the first points requisite in the electrolytic deposition of gold is that the liquor shall contain no solid matter, that is to say, that it shall be absolutely clear. Otherwise, the great surface which is presented by the cathodes and anodes serves to collect all the fine particles that remain in the liquor; necessarily settlement of any kind upon the metallic surface of the anode or cathode increases the resistance of the precipitating box and results in imperfect adhesion of the particles of gold to the cathode.

This difficulty is easily overcome by passing the liquid before precipitation through a sand filter, or through an intermediate vat of large settling capacity. The liquid which is drawn from frêsh slimes is much more readily clarified than the liquid drawn from accumulated slimes. The liquor from the accumulated slimes contains a considerable amount of iron and lime salts in solution, and the settlement of the fine clayey particles is retarded. This may possibly also be due to the organic matter which it contains.

Other substances in the liquid which affect the surface of the cathode, are those salts which are in solution upon entering the box, and are there deposited on the large surfaces exposed, or are electrolysed. Lime which has been used for settlement, and also to neutralize acidity, is in form of carbonate of lime, sulphate of lime, and hydrate of lime. This precipitates partly as carbonate and partly as sulphate upon the cathodes and anodes, more especially on the former, and in the opinion of the author, is precipitated partly by means of the electrolytic current. Then there are the products of the decomposition of the solution itself, which (in the case of iron salts, resulting from the decomposition of the pyrites in the ore) are separated in the form of Prussian blue and hydrates of iron. Then, again, there are the products of the decomposition of the anode plates.

The clearness of the solution depends largely upon the solubility of the anode. The iron plate anode of the Siemens & Halske boxes, with a properly proportioned current, is a very perfect anode, easy to be obtained in any quantity, and is easily manipulated and secured in the boxes. With a current density as low as 0.03 or 0.04 ampere per square foot, very little decomposition of the iron anode takes place. An anode three-sixteenths of an inch in thickness, and with a current density of 0.035 ampere per square foot, should last five years, and possibly much longer. There seems to be a limit of density up to which an iron anode will show very little corrosion, but beyond that point oxidation seems to take place more rapidly than the proportionate rise of current density would indicate. Where the division and tension of the current have been very carefully studied and regulated, very little decomposition of the anode need take place.

With the peroxide of lead anode which was discovered by Mr. Emile Andreoli in the early part of 1895, practically no corrosion of the anode takes place, and the author says he feels confident that its introduction on a large scale would prove satisfactory. (Since this paper of Mr. Butters' was written, this development has, in fact, taken place.—Ed.) With perfectly filtered solutions, and with a peroxide of lead anode, working with fresh slimes, and by watching carefully the amount of lime added to the slimes, there should be very little trouble in maintaining a perfectly clean cathode surface for the plating of the gold.

One point worthy of study by all chemists in connection with the maintenance of a clean anode surface, is to see, either how the lime salts can be prevented from precipitating in the boxes, or if any economical method cannot be devised to reduce the amount in solution. The author thinks it is next to impossible to find any substance that will economically replace lime in the settlement of slimes, but some means might be found to obviate its deposition from the solution in the precipitation boxes. The subject of the production of suitable anodes for precipitation of gold from cyanide solutions is probably not exhausted, but the field has been very thoroughly explored by able electricians and chemists, and, beyond the

two anodes mentioned, the author does not know any that will fulfill the required conditions.

The anode has attracted a good deal of study, but the subject of the cathode is not less interesting and important. Many substances have been tried, which have performed their functions more or less completely. Lead has been used in thick plates, in thin sheets, in ribbons and strips, and in the form of shavings while zinc has been used in the form of amalgamated plates, and as shavings; amalgamated copper plates have similarly been tried, together with iron plates and various other forms of iron; and the same with mercury. Zinc, copper, and iron in various forms have been utilized by Mr. Andreoli for this purpose; mercury has been used in the United States in the Pelatan-Clerici Process. Each of these various cathodes has its peculiar advantages. Lead strips are used everywhere in the plants using the Siemens process, except at the Central Works, where part of the boxes are charged with lead shavings; and at the Comet, zinc shavings are in use.

In the actual running or precipitation of the liquid in the Siemens & Halske box, there are only a few things to which it is necessary to give attention. Having set the current, and knowing the capacity of the precipitating plant for a certain grade of solution, all that is required for the period of one or two months is, at the commencement, to see that the connections have been properly cleaned, and are in order, then to keep a constant flow of clear liquid through the box, then to see that the same current is maintained throughout, after which no further attention is required. The guide as to when the clean-up should be made is the condition of the cathode.

The cleaner the cathode can be kept, the larger will be the amount of gold that can safely be precipitated upon it; and the steadier the current is kept, the more solid and perfect will the plating be. So long as the surface of the lead remains clean and the coating regular, so long the precipitation of the gold will take place; but under ordinary circumstances, such as prevail in our precipitating plants to-day, it is not usually advisable to retain the lead in the boxes for more than two months. Possibly, if the lead can be kept clean, three months might be given to the lower boxes, because they are generally cleaner than the upper boxes; deposition of the lime and other substances that tend to destroy the efficiency of the cathode is most apparent in the head boxes. The author concludes his notes on this subject by some complimentary remarks on the work of A. von Gernet, M. Torrente and G. Andreoli.

Electrode Connections for Electrolytic Vats.

A paper of Mr. A. von Dessauer deals with the electrical connections for electrolytic vats, used in the precipitation of gold. He distinguishes between permanent connections and detachable or movable connections. The permanent connections are left untouched for months and months, and are best effected by soldering or rivetting the wires to the main cable; all anodes in the industrial electrometallurgy of gold ought to be connected this way. On the other hand, the cathodes are to be removed at intervals of one or two months, and their connections must therefore be detachable.

A connection of the latter kind is the arrangement known as "mercury trough." It is a groove of a ¼ inch width by 1 inch depth, cut in wood and filled with mercury. The wires from the electrodes are simply dipped into it, which is a rapid way of effecting a contact. But in spite of that, this system is discarded, because the current has to travel a long way to the main through mercury, which has such a high specific resistance that a very considerable loss of voltage has to be sustained to overcome it. Several improvements have been tried to this trough by sinking copper wires to the bottom of the trough, and by connecting these to the main, or by replacing the wooden trough by bent copper tapes closed with soldered ends. None gave satisfactory results; the latter failed because the solder soon became amalgamated, brittle and leaky.

A dry metallic detachable connection, effected by using screws or holding-down bolts, is very good so far, but it is rather expensive, and neither rapid nor reliable. One way of doing it is by running a galvanized screw through the main copper cable in the partition of the precipitation box beneath, and by so pressing the wires of the single electrodes down with the aid of a small copper tape. But very soon these screws do not bite any more in the wood, and the contact becomes problematical. For this reason an alternation has been adopted by which the screws are stationary and pointing upwards, and the nuts (either ordinary or butterfly nuts) are adjustable, traveling downwards. This is a good connection, as there should be no loss of tension of current so long as a proper contact is effected. But it is doubtful whether this is achieved every time. The main, the wires from the electrodes and the copper tapes have to be cleaned after every clean-up with emery paper and files. This is expensive maintenance. It will take many hours to connect on all the cathodes after a clean-up, and it will take many days, according to the size of a plant to do this cleaning of the contacts. By the first operation the restarting of precipitation is retarded, whereas a plant cannot be in perfect running order as long as the latter operation is not completed.

Hardly any of these shortcomings are to be found with the Carlin tube. This tube is simply an ordinary pipe, best of iron, closed at its ends with screw plugs, and filled with mercury. As many holes are drilled into the top as electrodes have to be connected on. These holes might be round, and just a little larger than the connecting wires, or they might be oblong in shape, in case thin copper wires are used, which latter are best bent loop-shaped to sink through the slot, and to slip them well into the pipe.

The size of the pipe is calculated in the ordinary way in proportion to the current it has to conduct. Half-inch pipe will usually be found ample. One or both of the end plugs are split to receive the main, which will be held in its place by a brass screw. Instead of an iron pipe, others of brass or copper might be used, but there is then the danger of amalgamation. The pipe might also be replaced by a solid iron bar, with a long groove or single holes, to save mercury, in which case the holes must be a little larger, forming simply little cups filled with quicksilver.

The tube was then tried at the May Consolidated in place of the wooden mercury troughs. A 4-foot by half-inch iron pipe was laid down for two joining compartments in one box, and received twenty-six connections. The results were so encouraging that another pipe of brass was made, 8 feet long by half an inch diameter, and received the current from four neighboring compartments of two boxes, or the current from fifty-two cathodes in all. The exact data have been for the mercury trough; terminal tension 3.82 volts, decrease in tension 0.71 volt over the 8 feet of trough, or a loss of 18.4 per cent. (This represents an aggregate loss of 6.39 volt for the May plant, or close to 1,300 watts.) The temperature of the mercury rose at one end to 143.6° F. The distribution of intensity for the different cathodes is very irregular, one receiving twice and two-and-a-half times as much as another in the same compartment. It is therefore obvious that the solutions passing through these boxes encounter very different conditions in the different sections that the precipitation must be faulty.

The corresponding data for the Carlin tube are as follows: With the same tension at the terminals, the decrease over the 8 feet of tube amounted only to 0.015 volt, or 0.3 per cent loss. (Representing an aggregate loss of 0.135 volt, or 27 watts for the May plant provided all mercury troughs were replaced by tubes.) This loss is so insignificant that it can be neglected. It is the forty-seventh part of the loss sustained by mercury troughs.

No heating of mercury nor tube took place, the temperature being almost the temperature of the atmosphere; therefore,

the loss of quicksilver through evaporation is very small. The different cathodes of one compartment show almost the same intensity of current as a consequence of the tube acting as a splendid distributor. Better results will therefore be obtained for the precipitation. It will incur no risk to use a weaker current, as no solution will find a section in the box where it encounters insufficient intensity, and will be allowed to carry its gold away unprecipitated. This means a further saving of power and money.

At a later meeting Mr. von Dessauer described the following connection, used at a South African plant, which is a combination of the wooden mercury trough with metal. A broad copper tape stands vertically in a narrow slot, and is brought by half a twist to the main cable, and fastened with rivets or screws. The tape is large enough in size to carry the current. The receivers for the wires from the cathodes are little cups cut in the wood, semi-circular with ½-inch diameter. The efficiency of this connection, though not controlled by measurements is probably as good as that of the Carliss tube.

Influence of Temperature in the Cyanide Process.

In the presidential inaugural address of Dr. J. Loevy he referred to some laboratory experiments concerning the influence of temperature on the solution of gold by cyanide. In treating pyritic ore containing about four ounces of gold per ton, with a solution of cyanide at 40° C., the extraction obtained after four hours leaching was 14 per cent higher than that obtained by leaching the same ore with a solution of the same strength for fifty hours in the cold. He remarked that it would be for the practical engineer to find out whether a heating of the solutions is possible on a commercial basis.

Mr. G. A. Darling had gone through his note books from 1890 to 1898 to see if there was any appreciable difference in the extraction obtained during winter and summer months. By dividing the years into six hot months, and six cold months, he found that the average extraction for the cold months was 69.5 per cent, and for the hot months 72.2 per cent. By dividing the years into four seasons, each of three months, he found that the average extraction of six years working was for spring 68.3 per cent, summer 70.6 per cent, autumn 69.5 per cent, and winter 68.8 per cent. These results are given irrespective of any changes of the method of working.

Mr. A. von Gernet had made some experiments in which the exhaust steam from a small engine was run through four pipes in one of the vats from which the solution enters the extractor boxes. By assaying the residue he found that the extraction was increased by the heating of the solution. He did not give any exact figures.

Mr. J. R. Williams did not think that the higher extraction in the summer months has anything to do with the temperature; it is simply that there is a lot of water in the dam, and the organic matter becomes neutralized. Mr. F. F. Alexander also stated that during the cold weather they have a large amount of iron salts in the water, which affects the extraction. He thinks the same extraction can be got by cold water, provided it is pure, that one gets by hot water under the same conditions. Dr. Loevy stated, however, that by heating a solution to over 35° degrees C., the extraction is distinctly increased.

Potentials of Electrodes in Solutions.

Prof. A. von Oettingen, of Leipzig, Germany, presented two papers to the Society, giving, in the first, a general review of the modern theory of solutions, and in the second the application of the electrolytic dissociation theory to the explanation of the action in galvanic cells. From the latter paper the following remarks are taken which are interesting, since some points of the modern theory are here presented in a way which should appeal to practical men interested in the cyanide process.

Sugar molecules in solution exhibit osmotic pressure; solid sugar itself has a tendency to dissolve, which is analogous to the vapor-pressure of ice. When a piece of ice is placed in a vacuum it will evaporate until equilibrium is attained—that is to say, until the amount evaporated during any interval equals the amount condensed during the same time. Similarly, the sugar dissolves until an equilibrium between its dissolving tendency and the osmotic pressure is established.

Nernst first offered the following explanation of the actual tendency of metals to dissolve, or to change from the metallic to the ionic state. In this case the problem is somewhat more complex than with sugar-molecules, since the metallic atoms in changing their state must take up an electric charge; without this change they cannot dissolve except as colloids, as, for instance, colloidal gold in water. A piece of zinc placed in acid is instantly covered with a sheet of positive zinc ions, while the metal itself becomes simultaneously charged with negative electricity. The extent to which this takes place depends on the tendency of the metal to dissolve. The metallic zinc receives a negative charge, and the solution a positive one. In a very short time the distribution of the electricity is complete, but the newly formed zinc ions cannot pass into solution. They repulse the positive ions of the acid and attract the negative ones, but without combining since in a solution the number of cations and anions must be equal. If another metal be then immersed in the same solution, the repulsed ions will immediately cover it in the form of cations, and charge the metal positively until a certain positive potential is attained and an equilibrium established. This is the open galvanic cell.

Many metals—as, for instance, potassium and sodium—have so great a tendency to pass into solution that they assume the ionic state even in the absence of another metal. In this case the potassium takes the charge from the hydrogen cations, while the latter in the form of a gas, passes out of the solution. In the same way at a higher temperature zinc may expel hydrogen, but the process is accelerated by the presence of another metal, or of impurities in the zinc; in these cases the hydrogen becomes visible in the form of bubbles. With pure zinc the development of hydrogen is small.

Another point in which the dissolving of metals differs from that of sugar is the following: In a saturated solution of sugar the osmotic pressure equals the tendency of the solid sugar to dissolve. But the dissolving tendency of zinc is much greater than the osmotic pressure of the zinc ions, even in a saturated solution of zinc salt. The zinc, hence, acquires a negative potential in saturated solutions. Sugar cannot have any electrical potential at all.

The potential of various metals in saturated solutions is very different, since their respective tendencies to dissolve are sometimes greater and sometimes less than the osmotic pressure of their ions. Thus, copper in a saturated solution of cupric sulphate acquires a positive potential, and the fluid a negative one. In an open Daniell cell zinc has a negative potential and the copper a positive potential. As soon as these potentials are acquired, the process of ionizing stops in the open cell because an electrostatic equilibrium is attained. As soon, however, as the copper is connected with the zinc, a current is developed, the positive electricity from the copper ions entering the metallic copper, and from this passing on to the zinc, which is thus discharged. The copper ions having been thus discharged and deposited, a new sheet of cations passes out. At the same time zinc ions pass into solution, and a new sheet of zinc molecules assume the cationic state, leaving the metal itself negatively charged. In this manner a continuous current is set up.

When two metals are in contact no difference of potential exists, or merely a very small one, measurable only in thousandths of a volt; this is due to thermo-electric currents, and may be neglected. It may be noted that the term "couple"—as, for instance, of zinc and lead—was used formerly to express the idea that the electricity in a circuit was produced by the

contact of two metals. This theory of Volta, and of many philosophers until recently, is now known to be erroneous. We now understand that zinc exhibits a potential towards the solution in which it is immersed, as does also the lead. When the circuit is closed the electric current is allowed to pass from the lead to the zinc, and this process continues. In this sense only can the term "couple" be used, because the presence of a second metal is a necessary condition for a continuous electric current, although the electricity produced by contact is quite insignificant, and in no way the source of the current. The real source of the current is the energy derived from the zinc in its transformation into positive zinc ions. At the contact of the sulphuric acid and cupric sulphate in a Daniell cell there is likewise a small difference of potential but this is so small that it may be neglected, and the e. m. f. of the Daniell cell becomes, according to Nernst's theory, equal to

$$RT\left(\log\frac{P_z}{O_z} - \log\frac{P_c}{O_c}\right),$$

where R is the gas-constant, T the absolute temperature (= degrees C. + 273), P_z and P_c the tendency of zinc and copper respectively to dissolve (Nernst's "solution tension"), and O_z and O_c the osmotic pressures of the cations of zinc sulphate and copper sulphate, respectively. The quantities P_z and P_c are constant, while the osmotic pressures vary with the concentration. The electromotive force being greater in sulphuric acid than in zinc sulphate, the potential will decrease as more zinc ions enter the acid. On the copper side the reverse is the case, because the more cupric sulphate is in solution the greater is the potential, the osmotic pressure being greater than the tendency to dissolve. Since P_z is greater than O_z while P_c is less than O_c, the two terms of the equation constitute a sum, and not a difference. It is remarkable that potentials are independent of the chemical nature of the anions; the potential, for instance, of

Zn, $ZnSO_4$, $CuSO_4$, Cu, and
Zn, $Zn(NO_3)_2$, $Cu(NO_3)_2$, Cu,

being the same. The anion influences the degree of dissociation of the compound, and, hence, the acid radicle affects the potential indirectly by its influence on the osmotic pressure.

Such cells as Daniell's are reversible, if electrical energy be expended to drive the copper into, and the zinc out of, solution. The electrical energy required is P × 96,540 volt-coulombs (or wattsec.) for one gramme-equivalent of deposition of zinc and solution of copper. If an electrical source of energy be employed, of which the potential P_1 is less than P, there will be no current. If P_1 is greater than P, there will be both a current and a deposition of metal proportional to P_1 — P, and not to P_1 simply. In some cases of great interest the potential of a metal appears greater than usual. For instance, the potential of zinc in contact with sodic or potassic hydrate is greater than with sulphuric acid. The reason of this is that in the first case no zinc cations are formed, the zinc atoms passing into the anions with formation of an alkaline zincate. If there were no osmotic pressure due to zinc cations, the formula already cited would give an infinitely high potential, because O_z in $\log\frac{P_z}{O_z}$ would be nil. As a matter of fact, however, it is considered that a small portion of the anions ZnO_2 (with two negative- charges) are dissociated into Zn (with two positive charges and O_2 (with four negative charges). Such zinc cations may be termed cations of the second kind, or meta-cations. In the foregoing instance Zn (with two positive charges) would be a meta-cation, and O_2 (with four negative charges) would be a meta-anion. Exact formulæ for the potentials in such cases are not known, since the whole problem of the dissociation of complex ions has yet to be fully investigated. We know, however, that such decomposition occurs, since we obtain meta-cations on the cathode, and it likewise follows from Guldberg and Waage's law of chemical mass action.

Sometimes the sign of the potential changes. Copper, for instance in cupric salts is always positive. But it receives a negative charge when dipped into a solution of potassic cyanide; the molecules of copper here tend to be dissolved and become part of the univalent anion $Cu(CN)_2$. Copper dissolving in this manner may even expel the zinc from a zinc sulphate solution, the expression $\log\frac{P_c}{O_c}$ for copper being greater than $\log\frac{P_z}{O_z}$ for zinc. In such a combination it may be that the copper dissolves, and zinc is deposited in crystals on the zinc electrode without any current from an external source.

The same thing takes place with gold. Metallic gold immersed in most solutions has a positive potential, gold cations having usually a great tendency to assume a metallic state, while metallic gold dissolves with difficulty. This behavior is indicated by the popular term "noble," which is applied to such metals. In cyanide solutions, however, gold does not act the part of a noble metal, since it dissolves, as part of the anion. This exception to its general behavior is of the greatest practical importance, since, were it otherwise, the cyanide process would not exist.

The difficulty of recovering the gold from cyanide solutions is obvious, from this point of view. The electric current causes the univalent cation K to migrate to the cathode, while the anions $Au(CN)_2$ travel to the anode, as pointed out by Hittorf. How, then, is the gold deposited on the cathode? This can only be explained by assuming that the osmotic pressure of the univalent meta-cations of Au is sufficient to cause their deposition thereon. Since the anions containing the gold are migrating to the anode, it is obvious that the movement of the whole solution is a most important point, and greatly assists precipitation by counteracting the migration of the gold anion.

By electrolysis of a solution of Na_2PbO_3 the cations Na_2 and the anions PbO_3 carry the current; however, metallic lead is deposited on the cathode as a meta-cation Pb (with four positive charges), while the meta-anion O_2 (with six negative charges) is set free on the anode, together with the anion PbO_3 (with two negative charges).

To deposit any given metal on the cathode the potential of the electrical source of energy must be sufficiently high to overcome the potential of the metal in solution. Thus, in a mixture of salt solutions in water—as, for instance, of the nitrates of Ag, Cu, Cd, K, and Zn—if small currents are first employed, and the voltage subsequently gradually increased there is first deposited pure silver, then copper, then hydrogen, cadmium, and zinc, in the order given. All the cations in these solutions are traveling towards the cathode with a velocity depending in each case upon the concentration of the solution and a special constant. The deposition of a metal upon the cathode depends upon its osmotic pressure in comparison with its tendency to dissolve.

By using Ostwald's mercury "normal electrode," the potential of which is taken as—0.560 volt, the author determined the potentials of gold when dipped into various solutions at 25° C. The figures obtained were as follows:

Au, AuCl (conc.)	= — 1.64 to — 1.42	volts	(variable)
Au, $N.AuCl_3$	= — 1.134	"	
Au, Aqua Regia	= — 1.09	"	
Au, KCNS (sat.)	= — .26 to + .03	"	(very variable)
Au, KCN (sat.)	= + .50	"	
Au, K_2S	= + .14	"	
Au, K_2S_7	= + .21	"	
Au, Na_2S	= 0 to .136	"	

From the above it is observed that in cyanide solutions gold readily passes into solution, since there is no primary osmotic pressure to hinder the dissolving process.

Some potentials of various electrodes in saturated cyanide solution are added:

Saturated KCN with	Au = + 0.50	volts.	
" " "	Ag = + 0.536	"	
" " "	Cu = + 1.154	"	
" " "	Zn = + 1.196	"	

Furthermore, we have the potential of a Zn electrode in $ZnSO_4 = + 0.524$. Hence, it is obvious that in the combination Zn, KCN(sat.), $ZnSO_4$, Zn
we can expel the zinc on the right by the zinc on the left. And even in the combination

Cu, KCN(sat.), $ZnSO_4$, Zn

the zinc may be deposited by the dissolving of the copper, since, though the potentials are opposed, there is a plus difference; thus,

1.154 volts —(+ .52 volts) = + .63 volts.

Zinc Versus Electrolytic Precipitation.

In his inaugural presidential address Dr. J. Loevy remarked that in spite of the undoubted advantages of the Siemens & Halske process, the war cry will, for some time to come, continue to be "zinc versus electric precipitation." The speaker said that apart from the generally asknowledged fact that the Siemens & Halske process was, up to that time, the only precipitation process coming into consideration for the slimes treatment, it is to be credited with being the cause of important improvements in the zinc process, thus showing that competition is always beneficial to an industry. Furthermore, the Siemens & Halske process has been the impetus for a considerable amount of research work.

Mr. T. L. Carter took exception to the statement that the Siemens & Halske process is the only suitable one for slimes treatment. He has found the following process to be quite effective at the Crown Deep, which had originally six Siemens-Halske boxes (40 by 6 by 5 feet, divided into 9 compartments). At the time when he read his paper (October, 1898), only half of one box was used, that being sufficient for the zinc method of precipitation. A very important point is the preparation of the zinc. After it has been cut on the lathe it is taken to a trough which contains a solution of acetate of lead of about 10 per cent strength. The zinc is thoroughly washed and stirred in the solution, until it becomes of a dark hue. If it is not thoroughly stirred only the outside of the mass of zinc will become coated, the inside remaining quite bright. An empirical way to ascertain whether or not the solution is strong enough, is to look at the zinc and to see if it is sufficiently and thoroughly coated. After thus preparing the zinc, it is placed in the box and covered with the auriferous solution as quickly as possible, since leaving it in the air seems to adversely effect it.

The next important point is the addition of free cyanide at the head of the box. Twenty pounds of KCN are dissolved in an iron tank holding about 75 gallons of water. This 2½ per cent solution is allowed to run freely into the auriferous solution, entering the box for a period of about four hours, raising the strength of the solution passing through from 0.007 per cent to 0.025 per cent. When the 20 pounds of KCN are finished another 10 pounds are dissolved as before, and freely run into the box, taking a period of six hours, and raising the solution about 0.007 per cent higher. By no means should the addition of the cyanide, as described, be neglected, for it is found absolutely necessary at the commencement to let this free cyanide run into the box. Twelve or fourteen hours after starting, a slow drip is allowed to fall into the solution as it enters the box, bringing up the strength of the solution going through the box from 0.007 per cent to 0.008 per cent, and this is continued through the run of the box. The first four or five days the precipitation seems to be very quick, and almost perfect, but later the zinc becomes gradually "dead." The process was worked with success at the Crown Deep by Mr. W. K. Betty. While the use of lead in conjunction with zinc was patented by Mr. MacArthur at an earlier date. Mr. Betty claims originality for the conjunction of free cyanide, lead, and zinc, by which he gets an almost perfect precipitation from solutions so weak in cyanide that it was formerly considered hopeless to attempt to make them amenable to precipitation on zinc in an ordinary zinc box.

In the discussion which extended over several meetings Mr. A. von Gernet stated that he had tried the process for several months, and the difficulty which occurred was in the formation of a ferrocyanide of zinc, which, in the form of a white salt, covers the zinc and checks the precipitation. The more the solution gets saturated with iron salts, and the more that reaction takes place, the quicker the point will be reached where precipitation ceases. The time taken to reach this point depends in a great measure on the ore, as some ores contain much soluble iron, in which case the solution soon becomes saturated and the formation of ferrocyanide of zinc takes place quickly. In the treatment of acid slimes, which always contain a large proportion of soluble iron, the formation of ferrocyanide of zinc takes place almost immediately, and to such a great extent that unless there is added continuously a large amount of cyanide to the boxes there will be precipitation only for a few days. There seemed to be a general disposition on the side of many members to question the novelty of the process.

Mr. J. R. Williams expressed the opinion that the Siemens & Halske electrolytic process is specially suitable for impure ores. By impure ores he means where other metals than gold are freely soluble in cyanide, such as carbonate of copper, etc.; such an ore he has at Pilgrim's Rest, where the zinc in a very short time after being placed in the precipitation boxes looked like so many ribbons of copper. Mr. J. MacIntyre agreed with him that where large quantities of copper are present, the electrical method is the effective one. Mr. Williams stated that there is a great uncertainty of the Siemens & Halske process, since one day one gets good precipitation, and the next day one does not; he also claims that there are considerable losses of gold in the Siemens & Halske process. Mr. A. von Gernet remarked that wherever there was found an uncertainty in the working of the Siemens & Halske process it was always found to be due either to the fact that the box capacity was too much up to the limit, or else to stoppages in the power plant.

Mr. Carter gave the following comparative figures on the cost of the Siemens & Halske process, and the zinc-lead process on the same plant, although after the introduction of the zinc-lead process the tank capacity had been somewhat increased. For April, May and June, when the Siemens & Halske process was used, the total cost, comprising cyanide, lead foil, power and royalty was 27 cents per ton of slimes treated. During July August and September, on which an experimental run was made with the zinc-lead process, the total cost, comprising cyanide, zinc, sulphuric acid, power, lead acetate, was 21 cents per ton. During October and November, when the zinc-lead process was worked under normal conditions total cost was somewhat more than 12 cents per ton. He also stated that he had transferred the zinc after being used in a slimes plant over to their sand-boxes, and had been very successful in this respect. Mr. R. E. Hall gave some data in connection with the Siemens & Halske precipitation in the Ferreira slime works. After the first six months of 1898 he had a theoretical extraction of 80.18 per cent, and an actual extraction of 76.09 per cent; afterwards the theoretical extraction was slightly higher. In using the zinc process, although without free cyanide, he experienced much trouble. Mr. Durant claimed that in the great majority of cases the Siemens process has been successfully worked under the care of different men, many of whom had no technical training whatever, and the results they obtained left little or nothing to be desired. He ridiculed the claim of some mysterious disappearance of gold in the Siemens precipitation boxes.

Mr. H. T. Durant remarked that the addition of free cyanide is to prevent the formation of insoluble zinc compounds, which would stop precipitation. Mr. W. Bettel remarked that since the action of the free cyanide has long been known to be to dissolve the zinc compounds coating the zinc, he cannot find anything new in Betty's process. Since he is himself the inventor of an electrolytic rival process, he said he could not be

regarded as a supporter of the Siemens & Halske method, but due credit should be given to the latter. "The alleged 'eccentricity' of electrolytic precipitation said to exist is merely a stalking horse or bogey, put up by persons whose knowledge of electrometallurgy is slight, and whose opinions must therefore be accepted with reserve. Mystery is always a hobby-horse of the so-called 'practical' man." He had observed with regret, tinctured with amusement, that when the extraction of gold from slimes happened to be low in nearly every case the unreliability of electrical precipitation was cited as the cause, and there the matter ended, no effort, or very little, except in rare cases, being made to get at the truth, which might very often have been traced to causes very far removed from its assumed origin. He expressed his belief that the day is not far distant when the demand for "kindergarten processes" (suitable to persons of limited understanding) will cease, and men will have to fit themselves for working modern metallurgical processes which require a certain amount of skill and attention, and which, when properly worked, will yield more profit than methods which seem the acme of simplicity—and slovenliness.

Mr. M. B. Zerener criticised the comparative figures of Carter for the cost of two processes, especially on the ground that according to his figures a considerably greater cost of cyanide is charged for the electrolytic process than for the zinc lead process. Mr. J. R. Williams gave comparative figures for his working of the Siemens & Halske process during 1898, and for two months, working with the lead-zinc couple. In the following, the first number always refers to the Siemens & Halske process, and the second figure to the lead-zinc process: Theoretical extraction, 71.4 and 72.6 per cent; actual extraction, 54.9 and 70.15 per cent; working cost per ton, 85 and 82 cents; profit per ton, 97 and 141 cents. He therefore concludes that by the introduction of the lead-zinc process the actual extraction has been increased by 15.25 per cent, the working cost has been reduced by nearly 4 per cent, while the profit has been increased by 44.8 per cent.

Mr. Durant denied that this comparison is decisive. If in a slimes plant, where the Siemens process is installed, and 88 per cent actual extraction can be maintained over an average period of six month, on, say, 4 dwts. slimes (which is the case), then, when other plants can only obtain a 50 or 60 per cent extraction, it is not the process that is at fault. They have made a comparative test at the Robinson slimes plant, the plant being divided, and with the solutions separate, one part being run with the Siemens process, and the other with the lead-zinc couple. The results obtained from the lead-zinc side were most unsatisfactory, the process being very variable, very expensive as regards cyanide, and most wasteful in the method of clean-up. However, there were many reasons why bad results were had in this plant by the use of a lead-zinc couple. The principal one he believes to be due to the aeration of solutions, since it has been found by tests that the introduction of air into a zinc box redissolves the gold from zinc. It is therefore evident that well-aerated solutions will not yield the same results as unaerated solutions. He emphasizes that in the solution from slimes aeration is the most important feature. Consequently, even if using the lead-zinc couple, one could not recommend giving up aeration (although detrimental to precipitation), for the reason that in the treatment of slimes aeration in the presence of cyanide is the best-known method of dissolving gold. On the other hand, in the electric process, the benefit of aeration can be had in treatment without any detrimental effect in precipitation, as air in the solution does no harm. He then gave some information on an experiment made on a large scale comparing the relative merits and demerits of the zinc process, as against the Siemens electric process, both sides being well represented. For a few months the results obtained were for various reasons not such as would be indicative of the normal working of the electric process, for the reason mainly that one solution pump and one pipe line was used for both the zinc and the electric solutions. This introduced zinc into the electric precipitation boxes, while it is now well known that zinc is fatal to successful electric precipitation of gold by the Siemens process. The experiment was then stopped and was taken up again after a month. Mr. Durant gives the figures for the two following months, July and August, which show some superiority of the electric process.

Mr. W. H. Wood gave comparative figures for the first cost of installing an electrolytic Siemens & Halske and a zinc-lead plant for slimes treatment, for a one-hundred-stamp proposition crushing 500 tons per day, the only difference between the two plants being assumed to be in the extraction house. He gives as first cost for the zinc-lead process $2,190, against $10,712 for the Siemens & Halske process. These figures, of course, refer only to the first cost of the extractor houses, not to the cost of working.

Concerning the whole comparative test made with both processes (mentioned above by Durant), it appears that the electric process was in general somewhat less economical than the zinc process, but, as Durant stated, there were so many objectionable points that he refuses to accept the test as representing the normal running of the electrical process. He believes that the two months, mentioned above, in which the electrical process showed a slight superiority, were the only ones in which the conditions were equally fair to either side. The full figures for the working of the two processes during the whole run of the test may, however, be found in the proceedings; as mentioned before, they are, taken as whole, in favor of the zinc process.

In a paper on precipitation of gold from cyanide solutions, Mr. A. H. Hartley gave some facts which seemed to show that copper-bearing ores would seem to present no difficulties to the successful treatment of tailings and slimes by the usual zinc method of precipitation. Mr. J. R. Williams, however, remarked that his experience was that, while small quantities of copper do not effect precipitation at all, yet, when it comes to an excessive amount, the Siemens & Halske, or any other good method of precipitation will hold its own. He thinks the more impure ore is in that way, the more necessity there is for electrical precipitation.

THE RARE ELEMENTS.

By Victor Lenher, Ph. D.

(Concluded from page 13.)

The class of substances which are designated as the *rare earths* comprise a large number of bodies, some of which are fairly well defined as chemical elements, while with a large number grave doubts can be cast as to their simplicity. Indeed, to many chemists the term "rare earths" is a phrase which means a group of elements whose chemistry is in more or less of a confused state and tangle. The great problem presented by these substances is their similarity, and their similarities are so great, in many cases, that it is an arduous and painstaking labor to separate even the sharpest defined ones of them into even reasonably pure substances. Yet it is to this group of bodies that we owe our present highly perfected incandescent gas mantles, the manufacture and construction of which affords employment for thousands of men, and represents an investment of millions of dollars of capital.

The chemical reactions of the rare earth group are such as to call forth attention to their general resemblance to the more common earth alumina and to the alkaline earths magnesia and lime.

Among the rare earth metals are listed thorium, zirconium, yttrium, erbium, terbium, scandium, samarium, cerium, lanthanum, neodymium, and praseodymium. The existence of the above-mentioned has been established to most chemists in a

fairly satisfactory manner; at the same time, mention should be made of a number of earths for which much may be said for and against, so far as simplicity is concerned. Among these are holmium, decipium, phillipium, thulium, dysprosium, metacerium, and a number of unnamed earths.

With the above array of earths, each presenting his own individual claims for recognition, some of which may be well said to be substantial, while others are not, it is little to be wondered that the average well-informed chemist does not view the undertaking of an analysis of such a mineral as monazite or samarskite with feelings of pleasure. Again, the rarity of most of the earths, and the fact that so few find any practical uses are frequently obstacles to investigation. All the time when dealing with the rare earths, one must remember that frequently only a single reaction can be used to differentiate from other earths and not infrequently this reaction is a slight difference in solubility of a given compound. For example, in 1885 Auer announced that by the fractional crystallization of the double ammonium nitrates from a strong nitric acid solution, and repeating the operation hundreds of times, it was possible to separate the old didymium of Mosander into two earths, to which he gave the names Neodymia and Praseodymia. Again, yttria and erbia are separated by repeatedly heating the nitrates and fractional crystallization from dilute nitric acid.

It is particularly worthy of note when considering the simplicity of the earths to observe that Moissan in his work on the carbides of the rare earth metals always found that when treated with water the carbides gave a complex mixture of hydrocarbons containing not only methane, ethylene, acetylene, and even hydrogen, but liquid and solid hydrocarbons, while carbides of such elements as throughout give clear-cut compounds as aluminium and calcium, a single simple hydrocarbon is the only product formed.

The usual division made in the rare earths is the reaction with potassium sulphate in saturated solution, cerium lanthanum and the didymiums form double insoluble potassium sulphate, and are thus separated from the erbium group whose double sulphates are soluble.

The most important commercial point in the rare earths is the incandescent gas mantle. As early as 1826 Lieut. Thomas Drummond found that lime and magnesia when heated in the oxy-hydrogen flame became incandescent, and that zirconia was more refractory and gave an intensely bright white light. This gave rise to the idea of using a highly heated oxide as a source of light. While these lights have seen great service, the great objections have been the production of such a high temperature as the oxy-hydrogen flame and the difficulty of obtaining a lower candle power without a tremendous loss of efficiency. It was only about 1886 that Auer von Welsbach demonstrated that with the heat of a small Bunsen flame it was possible to produce a light of high candle power by directing the flame on a mantle composed of the oxides of thorium and cerium. The composition of the mantles on the market and in common use to-day is the normal Welsbach mixture of 99 per cent of thoria to 1 per cent of ceria. The best mantles when new give with the ordinary burner about 100 candle power. This high candle power rapidly drops at first and then falls slowly, the greatest cause being the volatilization of the ceria at the intense heat, whereby the composition of the mantle is materially changed.

Vanadium and *uranium* have received more attention in the past few years in this country from the commercial side than heretofore, largely due to the discovery of the uranium and vanadium deposits in Western Colorado. Very little of the ore is, however, worked up in this country; the most that is taken out is shipped to Paris. In the Colorado deposits uranium and vanadium are found together in what appears to be complex minerals. Uranium also appears in Colorado and in several places in the West as pitchblende.

The use of vanadium has been repeatedly suggested in the manufacture of high-class steels, tool steels, and armor-plate steels, but very little has been done outside of the experimental stages. Results have been obtained, however, which look promising—vanadium hardens steel and in addition the steel can be used at a high temperature. The chief uses which vanadium compounds have, are in calico printing, in the manufacture of aniline black and in the coloring of glass. The usual compound employed is vanadic acid.

Uranium has been repeatedly suggested for use in the manufacture of high-class steels, but very little uranium steel is to be found on the market at present. Considerable quantities of uranium are used in the manufacture of uranium glass, which gives a peculiar yellow green fluorescent appearance, and in porcelain painting to give a fine velvety black color.

Columbium and *Tantalum*, from their contradictory chemical characteristics, are frequently called the "metallic acids." Their principal source in nature is in the minerals columbite and tantalite, although quite a number of other rare minerals contain larger or smaller quantities of the elements as oxides. The usual method for extracting the oxides from columbite or tantalite consists in fusing the finely powdered mineral with potassium bisulphate. The fused mass is treated with water, then dilute hydrochloric acid, and digested with ammonium sulphide, which removes iron, tin, tungsten, etc. After washing with water, the purified oxides are dissolved in hydrochloric acid, potassium fluoride is added and the solution crystallized. Potassium tantalum fluoride separates out first in needle-like crystals, while the more soluble oxyfluoride of columbium appears in plates on further concentration. Both of the metals have been prepared in elementary condition, by reduction with sugar carbon, in the electric furnace by Moissan.

Neither of the metals or any of their compounds thus far have had commercial application.

Selenium is a particularly interesting element on account of its action towards light. The element is obtained in three allotropic forms, *viz.*, red amorphous, black crystalline, and black glassy. The red amorphous variety which is the form usually obtained by the separation of the element from one of its compounds at the ordinary temperature, is a non-conductor of the current. Under the influence of heat it is transformed into the crystalline variety whose conductivity increases enormously in the light as compared to that in the darkness. Both of these varieties are converted into the black glassy modification by heating to 217° C., the melting point of the element. When, however, the black variety is held for some hours a few degrees below its melting point, it is completely converted into the black crystalline form. This is the method commonly employed for the preparation of the so-called selenium cells. The usual form of cell consists of two copper wires wound spirally around a mica, glass, or porcelain plate. The space between the wires is filled with selenium; the whole apparatus is then heated for four or five hours to a few degrees below the melting point of selenium, when the black crystalline variety is produced. The selenium cell, thus prepared, enormously changes its resistance to a current when brought from the dark into the light. Many uses have been suggested for this interesting piece of apparatus, such as sending pictures over a wire, automatically lighting gas street lamps, etc. Unfortunately, selenium cells thus far have not been found to be permanent and reliable, and the reason for their deterioration has not been satisfactorily accounted for. The formation of copper selenide is probably one of the factors, but the whole subject is certainly one which merits further research. Selenium is found in nature in certain iron pyrites, and in some localities in natural sulphur; it is similar in its chemical characteristics and compounds to sulphur, though not nearly so pronounced a non-metal. One of the principal sources of selenium is in the flue dust deposits from the manufacture of sulphuric acid by the lead chamber process.

Tellurium in many respects much resembles selenium. In its

conductivity and in its action towards light there is, however, no resemblance. While its resistance is high, there is no fluctuation in the light as compared to the darkness.

Tellurium in nature usually accompanies gold; in fact, we have not only the rich telluride ores, but native tellurium itself usually carries larger or smaller amounts of gold.

The sulphide copper ores frequently carry small amounts of tellurium, and in electrolytic refining of copper, the slimes formed often carry considerable quantities of tellurium.

The telluride ores are the most refractory class of all of the gold ores, so far as economical treatment is concerned, and the methods for extracting the gold are proportionately expensive.

Thus far tellurium and its compounds have had no commercial value; in fact, in most cases, tellurium seems to be an element which in the commercial way should be rather avoided than cultivated. Small quantities of the element tend to destroy some of the most valuable properties of many of the metals and their alloys. The compounds of tellurium are poisonous, and in many cases the element as a contaminating substance is difficult to eliminate.

From the pure chemical standpoint, tellurium is original in being the glaring exception to the periodic law, its atomic weight, 127.5, is higher than that of iodine, 127, while theoretically it should be several points lower. A large amount of attention has been given to this point, particularly in the past few years, but thus far it has withstood all attempts to break the element down to more simple forms, and for the present we must accept the atomic weight which has successfully stood the tests of years of careful and elaborate experimentation.

Molybdenum and *Tungsten* are two elements which in many respects possess similar chemical characteristics. They occur associated together in nature, the one usually appearing as a contaminating material with the other. The chief source of molybdenum is the sulphide, molybdenite from which it is extracted by roasting, and the resulting trioxide is purified by sublimation. Molybdenum trioxide, commonly known as molybdic acid and the ammonium salt, find considerable application as reagents for the determination of phosphorus. The alkaline molybdates, especially sodium molybdate, are used in the production of bright blue colors on crockery, and molybdic acid or one of its salts is used to more or less extent in the dyeing of silk and wool. The production of metallic molybdenum by high temperature methods, need only be mentioned here, and as well the use of molybdenum in the manufacture of high-class steels.

Tungsten occurs in nature as wolframite, the tungstate of iron, hübnerite, the tungstate of iron and manganese, and scheelite, the tungstate of calcium. For the extraction of tungsten from these minerals, either fusion with sodium carbonate is resorted to when soluble sodium tungstate is formed, or treatment of the ore with nitric acid when the trioxide is obtained.

Tungsten compounds have considerable use, sodium tungstate is one of the best substances known for impregnation of fibres of various kinds for the purpose of making them fireproof. It is also employed as a mordant in dyeing. The partially reduced tungstates are the very important and beautiful tungsten bronzes which are so largely used as bronze powders and pigments.

It has been known for many years that tungsten, when introduced into steel, renders the latter extremely hard and tough, and it is largely to tungsten that we owe the valuable properties of our highly perfected self-hardening steels.

The *platinum metals* are commonly distinguished as two groups, the first embracing the light platinum metals, palladium, rhodium, and ruthenium while the second contains the heavy platinum metals, platinum, iridium, and osmium.

Of the first group, palladium is the only one which may be said to have a commercial importance, no important applications being made of rhodium or ruthenium. Palladium has the lowest melting point of any of the platinum metals, 1500° C.; it is more malleable than platinum, is steelwhite in color, and does not tarnish. On account of its resistance to oxidation and to the action of hydrogen sulphide, it is used in the construction of the mechanical parts of fine watches, fine balance beams, scales on delicate apparatus, etc.

Perhaps the most striking reaction of palladium is its property of absorbing hydrogen at the ordinary temperatures. It will, at and below 100° C., absorb sufficient hydrogen to form the hydride Pd_2H, while palladium black at 100° C. will take up nearly a thousand times its volume of hydrogen.

The heavy platinum metals are all important commercially, platinum so much so that little need be said here except to note that the commercial metal contains small quantities of the other platinum metals, and that this is considered to be beneficial.

Osmium is the most infusible of the group, and is extremely refractory toward reagents. The usual method of attack is to heat the metal mixed with common salt in a current of chlorine gas, when the double sodium chloride is found which is soluble.

Osmic acid is a readily volatile substance, is a very active substance, has a powerful odor, is extremely irritating and poisonous. The acid is used as a black stain for the cross hairs in optical instruments, and in biological work. The element in metallic form is employed in the preparation of filaments for incandescent lights.

Iridium is one of the most refractory metals, and could be used to replace platinum to a considerable extent in the manufacture of crucibles were it not for the fact that it absorbs carbon from the flame, and becomes converted to the carbide. While this carbide is not a stable compound its formation causes the crucible to have a comparatively short life. On account of the hardness, infusibility, and indifference to reagents of the metal, and as well, of the native alloy iridosmium, both find considerable use in the construction of fine bearings, knife edges for balances and in points for gold pens.

Chemical Laboratory, University of Wisconsin,
Madison, Wis.

RECENT IMPROVEMENTS IN DRY CELLS OF THE LECLANCHE TYPE.

BY ADOLF J. MARSCHALL.

The exciting liquid, used by Leclanché in his well-known cell, is a concentrated solution of NH_4Cl. Leclanché tried to replace the NH_4Cl by the chlorides of potassium and sodium, but the result was not satisfactory, because no combustion of hydrogen takes place, or, if it does, it is excessively small. The writer has found the same to be the case if a solution of $ZnCl_2$ is used.

The principal action in the Leclanché cell is as follows:

$$2NH_4Cl + 2MnO_2 + Zn = ZnCl_2 + 2NH_3 + H_2O + Mn_2O_3$$

Through secondary reactions several other products are formed, but they are not fully known.

Nearly all so-called dry cells consist of the elements used in the regular Leclanché battery, but no separate container is used, as the zinc pole is in the shape of a deep cup, that forms a container for the other materials. This zinc cup is lined on the inside with porous paper or plaster of Paris and the space inside this lining is then packed solid with a mixture of finely divided MnO_2 and granulated carbon, with the carbon pole in the center. The whole mass inside the zinc is dampened with a concentrated solution of NH_4Cl and sealed with pitch.

The more successful cells on the market do not contain NH_4Cl alone, but from 5 to 10 per cent $ZnCl_2$. If this $ZnCl_2$ is not added, the $ZnCl_2$ formed by the action of the cell, will sink down close to the zinc and local action will be set up between Zn in NH_4Cl and Zn in $NH_4Cl + ZnCl_2$. By the addition of the $ZnCl_2$, the local action is very much reduced.

When the cell has been used for some time, the free NH_3 will be strong enough to act on the zinc, and if sufficient has been

formed, the zinc cup will be perforated and the cell made worthless.

This presence of free NH_3 in the cell changes the chemical actions entirely, but what products are formed are not known.

We have just mentioned that the MnO_2 in the cell cannot be reduced by $ZnCl_2$, but the writer has found that by further addition of a *small* amount of NH_4Cl, which acts as a catalytic substance, the cell is able to produce as much current as if the liquid had been a concentrated solution of NH_4Cl. About 3 per cent NH_4Cl, with the $ZnCl_2$, will produce this action, and even if the current is run down to zero, the odor of free NH_3 is hardly perceptible when the cell is opened. The composition of this liquid, containing a large excess of $ZnCl_2$ is protected by letters patent.

In this way the local action and the action of the free NH_3 is reduced to a minimum and the result is a cell of great keeping quality and energy.

ELECTROLYTIC ZINC.

By Oskar Nagel, Ph. D.

In comparing the great amount of work of the last years in zinc electrolysis, with the results, we must be surprised to see the disagreeable proportion of the former to the latter. Involuntarily we think that this work was carried on without the proper system and foundation. I will try to show general lines along which a better result might be obtained.

The chemist, in working out a process, is starting work on a small scale, goes over slowly and continuously to a larger scale, and is ending the experiments at last on a manufacturing scale; during this work he is watching continuously the different stages of the reaction, and is changing the circumstances for getting the yield desired. Thereby he is *quantitatively* approaching his intention.

In trying certain reactions with a less known element, the work is advantageously started with a well-known element and carried on by going over to less known substances of the series of tension, connecting the known element with the substance to be worked upon. This is a *qualitative* approach to the solution of the problem.

In trying, for instance, certain zinc reactions, which in similar form can be successfully made with nickel, we will start with the latter, going over afterwards to cobalt, and after studying the reaction on cobalt, take up iron, thallium, cadmium and zinc.

The sequence of the metals from zinc to copper, according to their tension, is:

	Volt.
Zinc	0.51
Cadmium	0.16
Thallium	0.11
Iron	0.09
Cobalt	—0.02
Nickel	—0.02
Tin	—
Lead	—0.10
Hydrogen	—0.25
Antimony	—
Bismuth	—
Arsen	—
Copper	—0.50

The present stage of technical electrolysis can shortly be defined as follows. Copper is successfully made in solid plates. The details of this process are well known. There is so far no practical success in making electrolytic arsen and bismuth. Electrolysis of antimony has only resulted in powder. No solid plates are made out of lead (electrolytically). Tin is always obtained in loose powdered form. In trying to precipitate nickel out of salt solutions, no thick plates can be obtained, the precipitate being so brittle that it falls apart. No definite results are published on electrolytic cobalt, iron and thallium. We know only of small laboratory experiments with cadmium. However, it is well known that the electrodeposition in going from copper to zinc gets more and more difficult.

We see now that—especially of the metals *above* hydrogen—no successful technical electrolysis was made so far. For getting a satisfactory result in zinc-deposition, it will be necessary to work out at first all the details of lead electrolysis, going over them and changing, as it seems necessary, the conditions of the experiment to tin, nickel, iron, cadmium and at last to zinc. It is a long way from the electrolysis of lead to zinc, as is shown by considering that for precipitating lead out of normal salt solutions by means of hydrogen, the latter would have to have a pressure of 3.1×10^4 atm. In the case of zinc the required pressure would be 3.2×10^{25} atm.

It is probably incorrect to say that zinc electrolysis would have been farther advanced, by using the systematic way from copper to zinc, according to the increasing tension. But there can be no doubt that thereby much troublesome work would have been avoided, which started with incorrect and weak propositions and foundations. As Gauss, the mathematician, says, "If we experiment, we experiment with our thoughts."

FIRST MEETING OF THE NEW YORK SECTION OF THE AMERICAN ELECTROCHEMICAL SOCIETY.

In spite of very unfavorable weather, more than sixty members and guests assembled on the evening of January 26th in the Chemists' Club, New York City. They were welcomed by Prof. C. A. Doremus, who, in some well-chosen introductory words, dealt with the success of the Society, and with the role which electrochemistry plays in New York State and city. He explained that New York City was certainly entitled to have its local section.

The success of the first meeting of the section certainly justified the hopes entertained by those interested in the formation of this section. Not only the comparatively large number of members who came to attend the meeting in spite of pouring rain and melting snow, but also the lively and interesting discussions which followed the reading of each paper proved that the New York Local Section has a useful mission to fulfill.

The Commercal Electrolysis of Water.

A paper on this subject was presented by Prof. J. W. Richards, of Bethlehem, Pa., who first gave an historical review of the commercial systems of the electrolysis of water for producing hydrogen and oxygen. As electrolyte, caustic soda or sulphuric acid are used, with iron electrodes in the former case, and lead electrodes in the latter case, but the use of caustic soda with iron electrodes appears to be now considered to be preferable for commercial purposes.

The main problem to be solved in designing a cell for the electrolysis of water is, of course, to provide means by which the products of the electrolysis—oxygen and hydrogen—are kept separate from each other. Diaphragms are used for this purpose, and according to the nature of these diaphragms all the different commercial cells are sub-divided by the author into the three following classes. In the first class non-conducting porous diaphragms are used; the cell of Schmidt belongs to this type. In the second class solid partial partitions of a non-conducting material (like glass) are used, the cell of Schoop being an example. In the third class, metallic partial partitions are used, and the cells of Garruti and Schuckert are representative of this type. The author concluded his paper by some remarks on the cost and on the different uses of electrolytic hydrogen and oxygen.

In the discussion which followed, Mr. Carl Hering asked whether it would not be economical to use a high temperature, and Dr. Richards replied that 70° C. are stated to be the best voltage for the Schuckert system. Mr. Hering asked where the energy comes from, which corresponds to the expansion of the gases developed at the electrodes, whether it comes

from electrical energy or from the heat of the surroundings. Mr. C. J. Reed later explained that in his opinion the heat of the surrounding liquid must be considered to give the energy of the development of gases. Mr. Townsend Wolcott asked whether in the third type of cell with metallic partial diaphragms the current really passes through the diaphragms. This is not the case, as otherwise hydrogen and oxygen would be developed at both sides of the diaphragm. Dr. E. F. Roeber expressed the opinion that there is absolutely no new principle which distinguishes the third class (with the partial metallic diaphragm) from the second class (with the partial non-metallic diaphragm), since the partial metallic diaphragm is intended not to act as a bipolar electrode and behaves essentially like a glass plate. Dr. Richards explained that it is due to Garruti to have discovered that a metal can be used instead of glass or similar materials for the partial diaphragm, if only the e. m. f. at the terminals is kept below the value which would cause the diaphragm to act as bipolar electrode. Metallic diaphragms are, of course, preferable to glass, on account of durability. Dr. C. A. Doremus made some historical remarks on the subject.

THE THERMOCHEMISTRY OF ELECTROLYTIC DISSOCIATION.

A paper on this subject was presented by Mr. C. J. REED, of Philadelphia. This paper was essentially a criticism of Dr. J. W. Richards' paper on the same subject read before the last Niagara Falls meeting of the American Electrochemical Society (ELECTROCHEMICAL INDUSTRY, 1903, page 491). In this paper Dr. Richards considered the neutralization heat to be merely the condensation heat of water vapor from the gaseous to the liquid stat. From the circumstance that there is no quantitative relation between the formation heats and the solution and neutralization heats of compounds be concluded that ionization cannot be a destruction or dissociation of the compound and emphasized that in his opinion ions in solution are in the combined, instead of the dissociated state. In his calculations, however, he assumed that in a dilute solution of $2NaOH.400 H_2O$ an osmotic pressure of 12.34 atmospheres is exerted by the NaOH. Mr. Reed points out that this is about twice the osmotic pressure that would be exerted if the Na and OH were combined, so that he thinks that Dr. Richards' proof that there is no dissociation in dilute solution rests upon the fundamental assumption that there is complete dissociation when he calculates the osmotic pressure. Concerning the rule given by Dr. Richards on the calculation of formation heats, he says that there is an agreement among a considerable number of compounds, particularly the chlorides of the alkali metals. As we get further away from the alkalies, and further away from the chlorides in the list, the disagreements become more marked. He says that there are many compounds whose formation heat is positive, while it would be negative according to Richards' rule. As examples in which the disagreement is great, he gives mercury bromide and silver bromide.

In the discussion which followed the paper, Dr. Richards explained that the rule for calculating the formation heats, attacked by Mr. Reed, did not originate with him, but is much older, having been formulated by Hess and Tommasi. This rule was given by Richards as applying essentially to very dilute solutions, while Mr. Reed had picked out insoluble salts for which the rule is not assumed to apply. The rule holds in general for the majority for soluble salts, although even in this case there are exceptions which are assumed by the adherents of the dissociation theory to be due to incomplete ionization. Concerning his calculation of the osmotic pressure of NaOH he emphasizes that he did not make any concession on the fundamental proposition on the dissociation theory when he assumed the osmotic pressure to be 12.34 atmospheres. He simply took this value from an analogy with other electrolytes in which the osmotic pressure in very dilute solutions has been determined. Mr. Reed replied that in his opinion there is no such thing like an insoluble compound since every compound will dissolve if one only takes enough quantity of solvent. He also referred to the disagreement between the rule and the facts in the case of cadimum iodide. To assume a double osmotic pressure is, in his opinion, to assume a double number of molecules and this is the fundamental supposition of the dissociation theory. Dr. Richards replied that it is not necessary to assume double the osmotic pressure in his calculation in order to find a value of the neutralization heat which agrees fairly well with the facts; although the agreement is better if double the osmotic pressure is used instead of single. Besides, the value of the osmotic pressure in a very dilute solution is an experimental fact and independent of any theory concerning it.

FERRO-ALLOYS.

A paper on this subject was presented by Mr. AUGUSTO J. ROSSI, of New York City, who spoke on his researches on the manufacture of ferro-alloys in the electric furnace. Since these researches are well known to our readers from Mr. Rossi's article on page 523 of our issue of November, 1903 (see also December issue, page 583), these references to our former articles must here suffice. Mr. Rossi exhibited a very interesting collection of ferro-metals, obtained electrically, and other electric furnace products, including ferro-titanium, ferro-tungsten, ferro-molybdenum, ferro-chrome, ferro-silicon, ferro-manganese, copper-titanium, with accompanying slags and other accessory products.

A STRANGE OBSERVATION.

A brief note under this title was presented by Mr. I. J. MOLTKEHANSEN, of Rahway, N. J. By electrolyzing a pretty concentrated silver nitrate solution with two platinum wires as electrodes, he obtained a deposit of silver around the end of the cathode wire, but simultaneously a deposit was formed at the end of the anode wire. He asked for an explanation. Mr. C. J. Reed suggested that if the author had not made sure that the anodic deposit was really silver, it might have been silver peroxide, which could have easily formed under the conditions of the experiment. There would, of course, be nothing strange about that. Mr. Moltkehansen replied that he had not analyzed the anodic deposit.

After the by-laws of the local section had been adopted the meeting adjourned. Another meeting will be held during Spring.

SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.

INDUSTRIAL ELECTROCHEMISTRY.

Sterilization of Water by Ozone.—A paper on this subject by ERLWEIN (who, as chief engineer of the electrochemical department of Siemens & Halske in Berlin, has had considerable experience in this field) is published in the *Zeit. f. Elektrochemie*, January 1. The investigations by Siemens & Halske, Ohlmueller-Prall, Proskauer and Schueder, as well as the results obtained on a commercial scale in Wiesbaden and Martinikenfelde, show that ordinary germs are reduced by ozone to a smaller number than is generally possible in the best filtration plants, while the germs of cholera morbus, typhoid, etc., are always destroyed. He states that an estimate of the cost shows that the fuel consumption, i. e., the cost of energy for making ozone, is only a relatively small percentage of the

total cost per cubicmeter, and that under favorable conditions the method of purifying water by ozone is able to compete in cost with sand filtration. The calculations are based on a consumption of ozone of 2 grams per cubicmeter, which should always be sufficient, except in special cases. In Paderborn and Wiesbaden 1 to 1.2 grams are consumed per cubicmeter. In Figs. 1 and 2 the diagrams of the different systems of sterilizing and ozonizing apparatus are given. (For details the following references are given: Zeit. f. Elektrochemie, v. 7, p. 788; Tindal, Annales de l'Institut Pasteur, September, 1895; Revue générale des Sciences, July 17, 1896; Abraham-Marmier, Bulletin de la Société Internationale des Electricians, v. 17, No. 172, 1900; Otto, La Nature, 1899, No. 1377 and L'Industrie de l'ozone, extrait des mémoires de la Société des Ingenieurs Civils de France, February, 1900; Vosmaer, Zeit. f. Elektrochemie, v. 8, No. 30, 1902; Siemens & Halske, Elektrotechnische Zeit., v. 12, p. 340, 1891; Jour. f. Gasbel. u. Wasservers, 1901, Nos. 30 and 31, and 1902, No. 40, by Erlwein).

Daily Operation, About 12 Hours.

Cost of Operation for Ozonizing Plants for Treating 2000 and 200 Cubicmeters per Hour.

	Steam Power.	Steam Power.	Generator Gas Power
Output per hour....	2 000 cbm	200 cmb	200 cbm
Output per year....	9,000,000 cbm	900,000 cmb	900,000 cbm
Power	275 hp	45.5 hp	45.5 hp
Energy per year....	1,237,500 hp hours	204,800 hp hours	204,800 hp hours
Yearly cost of operation—			
a. 4% interest.....	162,500×0.04 $6,500	50,000×0.04 $2 000	50,000×0.04 =$2,000
b. 3% amortization	162,500×0.03= 4,875	50,000×0.03= 1,500	50,000×0.03= 1 500
c. Cost of fuel.	$4,250[1]	$1,383[2]	$725[3]
Wages and cost of maintenance	3,125	1,367	1,275
Total yearly cost of operation.....	18,750	6,250	5,500
Cost per cubic meter of water—			
a. 4% interest.....	0.052 cent	0.22 cent	0.22 cent
b. 3% amortization	0.054 " } 0.126 cent	0.17 " } 0.39 cent	0.17 " } 0.39 cent
c. Cost of fuel....	0.047 cent	0.15 cent	0.08 cent
d. Wages and cost of operation.	+ 0.082 cent } 0.035 " } 0.082 cent	+ 0.30 cent } 0.15 " } 0.30 cent	+ 0.14 " } 0.22 cent

[1] Coal consumption 0.8 kg per hp hour; coal price $4.25 per ton.
[2] Coal consumption 1.6 kg per hp hour; coal price $4.25 per ton.
[3] Anthracite consumption 0.61 kg per hp hour; anthracite price $5.60 per ton.

In Figs. 1 and 2 the upper series of pictures represents the different sterilization apparatus. I is the older Siemens iron tower for pressing ozone through the water; I[a] is the tower, now used, which is 4 meters high and filled with stones; II is the tower of Tindal, which is 8 to 10 meters high, and in which the ozone passes through a series of rain showers between cylinders with sieve bottoms; III is the tower of Abraham-Mermier, of about 4 meters height, the details of which are not yet known; IV the Otto tower in two parts, in which the water is mixed with ozone in the upper part, while in the lower part ozone passes again through the ozonized water while it passes through stones; V is the tower of Vosmaer (Electrochemical Industry, September, 1902, p. 31).

The lower row of diagrams represents the various ozonizing apparatus. Ia is the ozonizer of Siemens & Halske, using glass as dielectrics, cylindric discharge surfaces and water-cooling of the external earthed electrode; it is operated by 8000 volt alternating current. IIa is the 40,000 to 50,000 volt ozonizer of Tindal, with metal plates as discharge surfaces without a solid dielectric, the earthed electrode being water-cooled. IIIa is the ozonizer of Abraham-Marmier, characterized by a series of several glass plates of 1 square meter size, as discharge surfaces; the voltage is 40,000. IVa is the ozonizer of Otto, which is operated at 20,000 volts, without dielectrics. The details of the ozonizer of Vosmaer are unknown; it is stated to be operated at 10,000 volts without a solid dielectric.

Diaphragm Process for the Electrolysis of Chlorides of Alkalies. In the August and September issues of the *Journal de Chimie Physique*, P. A. Guye gives an account of an extended investigation of the electrolysis of the chlorides of alkalies in diaphragm cells. In reality the problem is a very complicated one, since, after electrolysis has been going on for some time, we get, not only the primary products of electrolysis; namely, chlorine and hydroxide, but also hypochlorites, chlorate, oxygen, etc.; the phenomena are still more complicated by diffusion and endosmosis (cataphoresis). The investigation is, however, greatly simplified, if the matter is looked upon from the point of view of Hittorf, and if we assume that we have essentially a solution of chloride in the anodic compartment, and a solution of chloride and hydroxide in the cathodic compartment. In the latter mixture, both the chloride and the hydroxide participate in transporting the current, according to their electric conductivities. If there was only NaOH in the cathodic compartment, for each 96,540 coulombs, passing through the cell, one gramion of Na is discharged at the cathode, and 1 grammolecule NaOH is formed, at the same time n grammolecules NaOH would pass into the anodic compartment (n representing the transport number of OH, a figure between 0 and 1); in other words the contents of hydroxide in the cathodic compartment would increase by $1-n$ grammolecules NaOH. But in reality we have in the cathodic compartment a mixture of NaCl and NaOH, and when 1 gramion Na is discharged, ($1-x$ grammolecules of NaCl and x grammolecule NaOH transport the current. Hence, only $n\,x$ grammolecule of NaOH are carried out of the cathodic compartment, so that $1-n\,x$ grammolecules NaOH are formed in the cathodic compartment for every 96,540 coulombs passing through the cell. This value $r = 1-n\,x$ is called by the author the "instantaneous output of the current," where n is Hittorf's transport number (a known figure) and x depends on the electric conductivities of NaCl and NaOH at the concentrations in which they exist in the cathodic mixture. In general r (which is a value between zero and unity) depends upon three quantities: the concentration of the chloride, the concentration of the hydroxide, and the temperature. But since commercial cells are generally operated at a constant temperature, the latter is no longer a variable quantity. Moreover, any diaphragm cell is worked by one of the following two methods. Either the cathodic liquid is maintained saturated with sodium chloride, so that its concentration is no longer variable and the "instantaneous output" r is a function of only the concentration c of NaOH. The second method is not to add anything to the cathodic compartment during electrolysis, but to start with an initial concentration of NaCl, which becomes smaller and smaller the more the concentration of NaOH increases, but in this case the concentration of NaCl depends necessarily on the concentration of NaOH, so that the instantaneous output r is again a function of only the concentration c of NaOH. The diffusion of NaCl from the cathodic to the anodic compartment is counterbalanced by the opposite transference of NaCl, due to electric endosmosis (cataphoresis). Hence, in general r may be set $= f(c)$. He has found that for the first of the above-mentioned cases in which the concentration c of the sodium chloride is maintained constant, the instantaneous output may be represented by the formula $r = \frac{1}{(1+ac)^{1/3}}$ and in the second case in which the concentration of NaCl decreases at the same time, as NaOH increases, the formula is $r = \frac{1}{1+ac}$

These formulas enable the author to simplify all further calculations. It appears that all the different secondary phenomena, mentioned in the introduction have no important influence on the production of caustic alkali, and that, in order to calculate the latter, it is sufficient to base all calculations on the "instantaneous output" r. By neglecting all other phenomena, one can predetermine with sufficient exactness the whole opera-

tion of a diaphragm cell under the two conditions of working mentioned above. The author gives an account of a series of measurements which prove the correctness of his theory.

Rapid Electrodeposition of Copper.—To deposit a metal from a solution by the electric current, it is necessary that the metal ions are present in sufficient number at the cathode. If a comparatively high cathodic current density is used, the danger is that the electrolyte in proximity to the cathode becomes poor in the ions to the deposited, and other processes start, especially the development of hydrogen. To counteract this tendency, it is necessary to artificially bring fresh electrolyte to the cathode surface, as, for instance, by means of stirring, rotating the cathode, etc. To impinge or inject the electrolyte against the cathode, has naturally the same effect, and a number of patents have been granted for such methods. These are summarized in an article in the *Electrochemist and Metallurgist*, of November, in which the methods of Thoffern, Grahams, Poore Dessolle and Harrison are briefly described and partly illustrated by diagrams.

THEORETICAL AND EXPERIMENTAL.

Action of Sodium and Potassium Amalgams on Various Aqueous Solutions. A long paper on this subject by FERNEKES is published in the December issue of the *Journal of Physical Chemistry*. Following the researches of Kahlenberg on the action of magnesium upon different aqueous solutions, the present author has studied in a similar way sodium and potassium, but on account of the violence of the reaction between these metals and water, and since these metals are so easily oxidized, their amalgams were used. A full account is given of the experimental work, and the results are summed up in tables and diagrams. If one makes use of the convenient term catalytic action, it is possible to classify all the reactions under two heads. First, there are those substances, which, dissolved in water, retard the action of the amalgam so that the speed with which the latter liberates hydrogen, is less than with pure water. These substances are "negative catalytic agents," and include most of the salts of the inorganic acids, also some organic compounds. Then there are those substances which

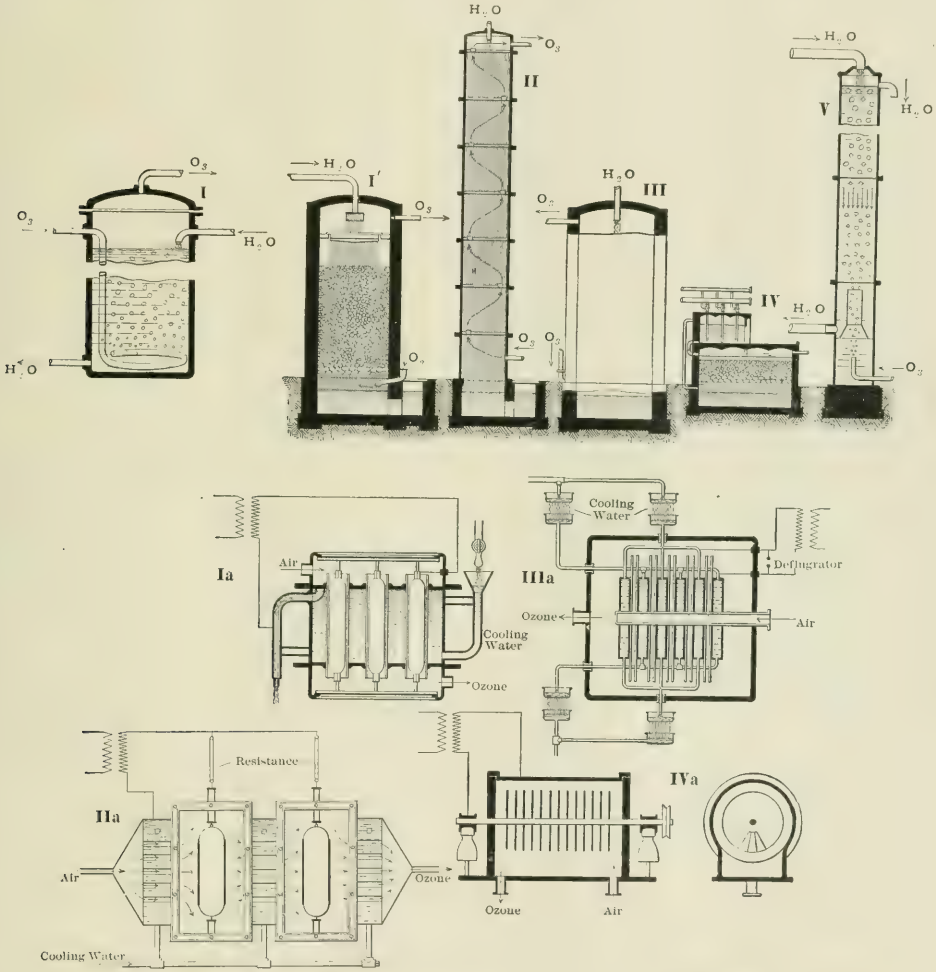


FIG. 1 AND II.—WATER STERILIZATION APPARATUS (I. TO V.) AND OZONIZERS (Ia TO IVa)

in solution increase the action of the amalgam. They are "positive catalytic agents," and include most of the organic substances employed, especially the hydro-carbons. The term catalytic action does not give an explanation of these phenomena, but merely serves as a convenient term for classification. The paper is of special interest, for the reason that the author tries to give an explanation on the basis of Kahlenberg's theory of chemical affinity between solvent and dissolved substance, in contradiction to the electrolytic dissociation theory.

According to Arrhenius, the slow action of sodium amalgam on a solution of sodium salts, is due to ions of sodium in solution, which by mass action would prevent the entrance of more sodium ions into solution. But this hypothesis fails to explain the slow action of the same amalgam on a solution of potassium salts. Chemical affinity, the affinity between solvent and dissolved substance, and the formation of a true chemical compound whose properties are different from either constituent, form the basis of the new theory. In the light of this theory, potassium chloride has about the same affinity for water as has sodium chloride, on account of the similarity of the two salts. The water in each case is held with the same degree of tenacity, and the action of the sodium amalgam on the new compound suffers an equal retardation in both cases. Concerning the majority of the organic substances investigated ("positive catalytic" agents), he remarks that as they are considered undissociated in aqueous solution, the ions cannot be held responsible for the peculiar behavior of these solutions on sodium amalgam. He assumes again the formation of a new compound, which must, in this case be extremely unstable toward sodium amalgam, since the action is more rapid than with pure water. The assumption of such unstable compound is nothing extraordinary. Numerous instances of the great reactivity of such unstable compounds are known. As an example, is mentioned that nitrous oxide is a more reactive compound than either of the elements of which it is composed. A splinter of wood will burn even more violently in nitrous oxide than in pure oxygen. Since the rate of action of the solutions on the amalgam is not proportional to the number of dissolved molecules, it appears that the first particles of the substance going into solution are attracted more strongly by the water than are the particles which enter when the solution is already partially saturated. The firmness with which the particles are held by the water diminishes with increasing concentration. The author concludes by saying that to solve the nature of catalytic reactions is one of the most important problems of modern chemistry. Catalysis plays an important role, not only in pure science, but also in many branches of chemical industry. The manufacture of indigo from naphthalene, and the manufacture of sulphuric acid are two of the numerous reactions, termed catalytic. The author says that many of these catalytic reactions find a ready explanation by the application of Kahlenberg's theory, and by using the term solution in the broad sense, which includes solid, liquid and gaseous solutions, it is thought to be not improbable that all catalytic reactions can be explained satisfactorily. It is then simply the attraction between solvent and dissolved substances and the formation of a true chemical compound which is more or less stable, and which may be made up of more than two substances, which is set down as the cause of the different rates of reaction.

Iron Salts in Voltameter Solutions.—The presence of iron in the sulphuric acid solution of an oxy-hydrogen voltameter has been shown by Elbs to decrease materially the amount of gas evolved. He points out that elements which have two different valencies should be eliminated from the solution of such a voltameter, because otherwise successive reduction and oxidation take place, reduction of ferric to ferrous sulphate at the cathode and oxidation at the anode. The actual amount of gas evolved depends on various conditions: On the rate of diffusion of ferrous salt to the anode, and ferric salt to the cathode, on the current density, and on the concentration of iron in the solution. The effect of a low current density is to cause a larger decrease in the gas product. In a paper by Bell, published in the December issue of the *Journal of Physical Chemistry*, attention is called to the fact that according to experiments of Schwab and Baum, the effect of iron in the solutions of a copper voltameter is practically negligible. The two sets of experiments, the one by Elbs, and the other by Schwab and Baum, are comparatively contradictory, but they have one essential difference. In the oxy-hydrogen voltameter, platinum electrodes are used, while in the copper voltameter there is a soluble anode. The oxygen which appears at the anode in the first case oxidizes ferrous sulphate to ferric sulphate, while in the second case copper goes into the solution. The amount of gas evolved in the first case is further diminished, because of the reducing action of hydrogen on the ferric sulphate. In the second case no ferric sulphate is produced except by oxidation by the air, the rate of which oxidation is quite low. Two experiments are described to prove that the two cases are not contradictory.

Radio Activity.—It is difficult to follow closely all the new investigations concerning radio activity. Those who are interested in a concise and authoritative summary of recent researches on this subject may be referred to an article of Curie, published in the December issue of the *Journal de Chimie Physique*. The author discusses the subjects under the following headings: Radioactive substances; the different radiations given off from radioactive substances; heat developed by the salts of radium; induced radioactivity and radioactive emanations. The article is concluded by a list of recent literature on the subject.

Batteries.

Edison Nickel-Iron Battery.—While nothing so far has been published in this country on details of manufacture of the active materials used in the Edison iron-nickel accumulator, some information on this point is given by Janet in a paper read before the International Society of Electricians in Paris, as noticed in the London *Electrician*, December 25. The mixture of iron and protoxide of iron which constitutes the active material of the negative electrode was obtained by passing a current of hydrogen over pulverized sesquioxide of iron, Fe_2O_3, at a certain temperature, which Edison himself has said ought to be 480° C. The reduced iron is then very slowly cooled in a current of hydrogen and washed in water; it thus loses its property of igniting, or at least of oxidizing, when exposed to air. The mixture of iron and protoxide of iron, rich in protoxide, is a bad conductor, but conductivity was formerly imparted to it by the addition of small pieces of graphite, to the extent of 1 to 4, and from this mixture rectangular briquettes were formed under a pressure of 4300 pounds per square inch. Now, however, graphite has been abandoned in connection with the active iron material, and a different process of manufacture is employed. The iron is not raised to quite so high a temperature, and, therefore, probably contains less protoxide; it is then mixed with ammoniated copper and oxide of mercury, and, the iron reducing the compounds, there is finally obtained a mixture containing 64 per cent of iron, 30 per cent of copper, and 6 per cent of mercury. Each particle of this mixture is, according to Edison, made up of a grain of iron covered by a porous envelope of copper amalgam, in a very finely divided state, together with a small quantity of an oxide of iron.

Miscellaneous.

Metal and Mineral Production of the United States in 1903.—Following its well-known custom, the *Engineering and Mining Journal* presents in the January 7 issue a great amount of valuable statistical information on the year 1903, with special reviews of different metallurgical industries and metal, mineral and chemical market. From these statistics the following table of the output of different materials in 1903 in the United States is extracted:

	Production in 1903.	Value.
Aluminium	7,500,000 lbs.	$2,325,000
Copper	670,880,000 lbs.	88,334,770
Gold	3,600,645 troy oz.	74,425,340
Pig Iron	17,942,840 long tons	265,554,092
Lead	289,030 short tons	24,492,402
Nickel (from Canadian and New Caledonian ores)	11,200,000 lbs.	4,872,000
Quicksilver	29,103 flasks	1,295,085
Silver (from domestic ores)	56,519,793 troy oz.	30,520,688
Zinc	156,318 short tons	16,582,344
Arsenic	590 short tons	35,400
Bauxite	40,700 short tons	179,080
Carborundum	4,724,000 lbs.	472,400
Coal, bituminous	283,406,691 tons	334,056,624
Coal, anthracite	73,390,000 tons	150,449,500
Coke	25,200 000 short tons	56,700,000
Cobalt Oxide	18,800 lbs.	42,300
Copper Sulphate	38,773,944 lbs.	1,628,516
Copperas	20,700 short tons	134,550
Fluor-spar	29,300 short tons	149,500
Graphite, crystalline	4,177,020 lbs.	154,549
Graphite, artificial	1,938,000 lbs.	160,479
Lead Pigments:		
White Lead	112,700 short tons	12,328,024
Red Lead	12,300 short tons	1,385,900
Litharge	12,400 tons	1,326,800
Orange, mineral	1,000 short tons	168,000
Limestone Flux	9,509,790 long tons	5,507,310
Phosphate, rock	1,477,600 long tons	5,328 018
Pyrites	196,970 long tons	778,031
Sulphur	12,054 long tons	292,155
Zinc white	59,810 short tons	5,005,394
Zinc Ore (exported)	37,619 short tons	342,800
Zinc Lead Pigment	4,500 short tons	253,125

Iron and Steel Alloys.—The first issue (January, 1904) has appeared of the *Iron and Steel Metallurgist,* which is an outgrowth of the Metallographist. Besides the portrait of Prof. Howe, and various other articles and reviews, it contains an illustrated article by HADFIELD, the well-known pioneer in the field of iron and steel alloys. He discusses briefly the properties of carbon steel and the alloys of iron and manganese, silicon, aluminium, chromium, nickel, tungsten, cobalt, copper, titanium, molybdenum, vanadium. Since he discusses the properties of these alloys very concisely, his remarks cannot be briefly abstracted, but it may be noticed that he does not seem to entertain great hopes for especially good results from the rare metals. For instance, concerning the alloys of iron and vanadium, he says that "It is claimed that this metal greatly increases the elastic limit, but it is doubtful whether this is so, except in the presence of carbon; that is, its action is not unlike that of chromium, though lesser percentages are stated to give the same effect as the latter metal. In view of its even now very high first cost, why use so expensive an element when a much cheaper one, such as chromium, appears to answer the same purpose? The writer has produced steel containing nickel and chromium that gave higher elastic limit and tenacity, also comparatively higher elongation than shown by results of iron with vanadium." Concerning alloys of iron and silicon, he says that experiments which may prove of extreme importance regarding the effect produced by silicon upon the magnetic properties of iron are in progress. A summary of the properties of the different alloys is given in form of tables and diagrams. At the conclusion the author remarks that he has produced alloys with tensile strength all the way from 18 tons up to 110 tons per square inch, and with elongations from nil to 70 per cent, but, singular, as it may seem, notwithstanding the important part played by all these new iron alloys, carbon steel maintains its premier position in determining the practical field of the various products. In other words, there are few, if any, iron alloys in which, apart from the effect produced by the special element added, the presence of carbon is also unnecessary. Therefore, whether one is a carbonist or allotropist in theory, one has to admit that carbon alone is the predominant factor in determining the utility of the alloy.

Color Photography by Electrolytic Means.—In an article published in the *Zeit f. Elektrochemie,* November 19, RIEDER calls attention to the fact that thin anodic deposits often show very beautiful colors. He has tried to utilize this phenomenon in connection with the problem of photography in colors, and describes a series of preliminary experiments, which he has made in this direction. The methods used by him are described in detail, but the gist of them is that he first produces a picture on a sensitive plate, and then brings the plate as anode into an electrolytic cell. He really thus produces beautiful colors, but it is a pity that the colors are not those which they should be. He gets, for instance, blue where he ought to get red, and it seems that it is not always certain what colors one gets by such a method.

Anti-Friction Metal.—The same author, RIEDER, describes in the *Elektrotechnischer Anzeiger,* of December 13, an anti-friction metal consisting of graphite grains embedded in copper. If a copper surface in which copper graphite grains are embedded, rubs against another metallic surface, then the wear and tear takes away, not only the copper, but also graphite, and the graphite, by coming between the two rubbing surfaces, diminishes the friction and counteracts the wear and tear. He thinks this copper-graphite metal to be suitable for various purposes; for instance, for dynamo brushes. The method of producing this anti-friction metal is an electrolytic one. In a mould, the surface of which is made conducting, a layer of graphite grains (the best for this purpose are said to have the size and irregular form of carborundum No. 30) is placed, and copper is deposited electrolytically, so as to fill the spaces between the grains; after these are filled up, another layer of graphite grains is placed upon the first one and electrolysis is continued, etc.

Bitumen in Insulating Compositions.—The December issue of the *Electrochemist and Metallurgist* contains SUTHERLAND'S full paper on this subject, an abstract of which was given on page 4 of our January issue.

Chemistry of Explosives.—In a paper published in the *Zeitschrift f. Elektrochemie,* January 1, WILL gives an historical sketch of the progress made in the chemistry of explosives in connection with the development of organic chemistry.

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By GEORGE P. SCHOLL, PH. D.

ELECTRIC FURNACES AND FURNACE PRODUCTS.

Process of Manufacturing Alkali Cyanides.—P. Dankwardt, Deadwood, S. D. Patent 746,795, December 15, 1903. Application filed June 10, 1903.

The process consists in heating a mixture of an alkaline earth nitride, preferably magnesium nitride, an alkali salt, and an alkaline earth carbide, in the electric furnace. The latter is water-jacketed, and two electrodes are introduced into it, passing insulated through opposite sides of the furnace. Pipes are arranged above the electrodes for the purpose of supplying gaseous nitrogen to the interior of the furnace. The ingredients which compose the charge are mixed in about the following proportions by weight: 100 parts of magnesium nitride, 85 parts of sodium fluoride, and 65 parts of calcium carbide.

This mixture is charged into the furnace until the latter is filled above the nitrogen supply pipes. The remainder of the charge is composed of 85 parts of fluoride of sodium, and 65 parts of calcium carbide. After the current is put on, nitrogen is introduced into the furnace. The reaction between the constituents of the charge is expressed by the formula:

$$Mg_3N_2 + 2NaFl + CaC_2 = CaFl_2 + 2NaCN + 3\ Mg.$$

The magnesium vapors react with the nitrogen and reform magnesium nitride, which again interacts with a fresh portion of the charge. It is important to have no oxidizing substances present in the constituents of the charge, or in the gas introduced, as they will lower the yield of sodium cyanide considerably, owing to the formation of alkaline carbonate, instead of the cyanide. The product, consisting of a mixture of sodium cyanide and calcium fluoride, is drawn from the furnace through a tapping hole, and the mixture either sold as such, or refined into pure cyanide.

Process of Simultaneously Producing Alkali Cyanide and Alkali Metal. Paul Dankwardt, Deadwood, S. D. Patent 746,796, December 15, 1903. Application filed June 10, 1903.

The inventor proposes to heat a mixture of the nitrite of an alkali metal with another alkali metal salt, and the carbide of an alkaline earth metal, under exclusion of the air. He prefers to use sodium nitrite and carbide of calcium, while the other alkali salt may be any salt which does not contain oxygen. The operation is carried on in a water-jacketed electric furnace, the two electrodes of which are introduced opposit each other, a short distance above the bottom of the furnace. The latter is provided with a tapping hole and an outlet pipe, which carries the metallic vapors to a receptacle. The charge is made up of 138 parts, by weight, of sodium nitrite, 195 parts of sodium fluoride, and 255 parts of calcium carbide. The reaction is stated to be,

$$2NaNO_2 + 3CaC_2 + 6NaFl = 2NaCN + 4CO + 6Na + 3CaFl_2.$$

Sodium sulphide may be used instead of the sodium fluoride, in which case calcium sulphide is formed. The fused mixture of the cyanide and fluoride, or sulphide, is withdrawn from the furnace by the tapping hole, while the alkali metal volatilizes and passes into the receptacle mentioned above.

Manufacture of Sodium. Thomas Ewan, Glasgow, Scotland, assignor to the Cassel Gold Extracting Co. Patent 745,958, December 1, 1903.

The inventor proposes to electrolyze caustic soda in a vessel, which is heated from the outside, and which is provided with a diaphragm. The latter is made of alumina, which will combine with the caustic soda to form sodium aluminate, or it is made of sodium aluminate in the first place, its structure in either case being that of unglazed porcelain. The inventor claims that when fused caustic soda is electrolyzed, sodium, together with a small quantity of hydrogen, is formed at the cathode, while oxygen and water are formed at the anode. He concedes that previously to this invention sodium has been made by the electrolytic decomposition of sodium hydroxide on a manufacturing scale, but claims that usually the water formed at the anode has been allowed to remain in the electrolyte. Under these circumstances he claims that the whole, or a larger portion of the water reacts with the sodium separated at the cathode, thereby reconverting about one-half of it into sodium hydroxide. By his invention, however, the water is isolated in the portion of the electrolyte surrounding the anode, from which it evaporates as quickly as it is formed, and this may be precipitated by passing a current of air over or through the electrolyte in the anode compartment. He omits, however, in propounding this novel theory of the electrolysis of fused caustic soda, to state where the water, which he claims is formed at the anode, is to come from. Blowing air through or over the caustic melt would result in the formation of a good deal of carbonate with consequent thickening of the melt.

Apparatus and Processes for the Electrolytic Production of Metals and Compounds.

Bleaching Process. M. Ruthenburg, Harrisburg, Pa. Patent 747,234, December 15, 1903. Application filed February 14, 1902.

The process described in the specification is intended for bleaching substances such as paper pulp and like materials. The stuff to be treated is mixed with an aqueous solution containing 20 per cent sodium chloride, in such proportion that the material is not only thoroughly impregnated with the solution but is also brought to such a consistency as to travel readily through the apparatus. The apparatus consists of a rectangular vessel, into which the electrodes are suspended from above, openings being provided in the cover for that purpose. A series of plates is disposed on the bottom of the apparatus, the plates being arranged midway between the electrodes. The terminals of the source of current are connected to the first and the last of the series of electrodes. It has been found advantageous to mix with the above solution of sodium chloride a solution which contains 10 per cent of hydrated oxide of calcium the object of the latter being to take up any chlorine liberated from the sodium chloride. Satisfactory results are stated to have been obtained by exposing the saturated material to be treated for approximately five minutes between electrodes, the current density at which was one-half ampere per square inch of electrode surface exposed to the mixture, at a pressure of 3 volts. The material to be treated is moved through the apparatus by a pump or other convenient means and in its progress it comes into contact with the surfaces of the electrodes.

Electrode. H. Blackman, New York. Patent 745,412, December 1, 1903. Application filed December 8, 1896.

The specification describes a mechanical construction for electrically and mechanically connecting the electrodes and keeping them properly spaced apart in the electrolyte, providing also for a possibility of readily removing any one electrode without disturbing its neighbors. For the purpose of keeping the electrodes apart, stops or buttons of glass or porcelain are provided which are formed as short screws adjustable and preferably applied to the cathode. For the purpose of protecting the electrodes from corrosion near the surface of the electrolyte, each of them is provided with a band or layer of glass or vitreous glaze. The electrodes are provided with arms or elbows, which rest upon the respective bus-bars and are held to them by a clamp of special construction. The iron anode plates are formed by casting or forging, and are then exposed to oxidizing agents under such conditions as to convert the exterior portion into magnetic oxide of iron, the treatment being continued until the oxide is of sufficient thickness to be impermeable to the chlorine set free during the electrolysis, the electrodes being primarily intended for use in the elctrolysis of sodium chlorid.

Apparatus for Refining Metals. A. Schwarz, New York, Patent 746,748, December 15, 1903. Application filed April 10, 1903.

The specification describes an arrangement for the refining of metals, in which the refining tanks are arranged in tiers in such a manner that the solution containing the metal to be refined flows from the lower part of the upper tanks into the next lower series of tanks. In order to obtain a rapid circulation of the electrolyte, and yet not be disturbed by the consequent stirring up of the slimes, the inventor interposes filters between the upper and the lower tanks through which the solution has to pass and which retain the slimes with which it is charged. The refining tanks are constructed preferably of wood, double-walled, the space between the two walls being filled with pitch or other suitable material. Each tank is provided with means to procure a constant flow of solution and rests in a trough-like support, in which filters are located below the outlet valve from the tank. The bottoms of the tanks are made V-shaped, so that the electrodes do not rest upon the bottoms. From the

last row of tanks the solution flows into a heating tank whence it is raised by a pump to pass again through the tanks. It is claimed that the electrolytic action is facilitated by reason of the rapidity of circulation of the solution and that the latter is kept free from slimes, with the effect of producing an even and increased deposit of metal.

Method of Finishing Metal Articles. Charlotte R. Manning, Meriden, Conn. Patent 746,724, December 15, 1903. Application filed January 5, 1903.

The invention relates particularly to finishing the surfaces of porcelain or enamel-lined vessels the object being to prevent their scaling off, when the lining of the vessel is fired in order to harden it. The invention is carried out by first polishing the exterior of the vessel which is to be treated and then giving it a coat of nickel copper or other material by electroplating. The interior of the vessel is then given an enamel lining, and the vessel is fired to set the lining. After the firing the exterior surface is removed with a grinding or polishing wheel, or by acids, and polished for the final finish of nickel, silver or other material by electroplating. The first coating so protects the exterior surface that no scales are formed.

STORAGE BATTERIES.

Battery Element. C. B. Schoenmehl, Waterbury, Conn. Patent 737,285, August 25, 1903. Application filed May 19, 1902.

The object of the invention is to secure a battery electrode which will give the greatest amount of power and life. The electrode is preferably formed of oxide of copper, which is first mixed with suitable solutions and then compressed or molded into shapes which have a wedge-shaped cross-section, being thickest at the top and tapering down to a narrow edge at the bottom. After being molded, the electrode is solidified by being compressed and baked.

Galvanic Battery. C. B. Schoenmehl, Waterbury, Conn. Patent 737,286, August 25, 1903. Application filed May 1, 1903.

The inventor proposes to construct copper oxide electrodes in the form of an annular body, thickest at the top and tapering toward the bottom. Several shapes of electrodes, which embody this idea, are given.

Dry-Cell Battery. E. R. Gill, New York. Patent 738,025, September 1, 1903. Application filed December 20, 1901.

The inventor emphasises the difficulty of filling in the powdered compound which constitutes the electrolyte of dry cell, in such a manner that it is not packed too tightly nor too loosely. In the first case there is not sufficient room for the gases to escape and the cell is liable to burst, while in the second case the internal resistance is too great. The inventor claims to secure an advantageous result, by first filling the cell with the powdered electrolyte, applying moderate pressure, and then forcing a pointed electrode into the center. The preferred form of electrode looks like a rod with a tapering screw thread, but it may only be plain point or conical. When the electrode is in position, the cell is closed in the usual manner by a suitable sealing material.

Electric Storage Cell.—J. A. Lyons and E. C. Broadwell, Chicago. Patent 744,216, November 17, 1903. Application filed January 26, 1903.

The object of the inventors is to provide a light and cheap accumulator cell, and for this purpose they propose to employ a metallic containing jar as cathode, and a porous body of carbon, placed inside of the latter, as anode. The jar is filled with either a paste of ground or granular carbon and lead chloride, bromide or iodide, or a solution of the chlorides, bromides or iodides of zinc, cadmium, cobalt, nickel, iron, tin or copper. The inventors state that they take advantage of the fact that charcoal, when compact, is able to condense and retain within its pores about 200 times its volume or three-quarters of its weight of chlorine gas and a larger quantity of liquid bromine. The carbonaceous anode is intended to form a carbonaceous wick to "support bromine against gravity," or to condense chlorine. In practice the inventors prefer the haloid salts of lead, cobalt, nickel, cadmium or zinc. They state that electrolysis of such salts as named above has been mostly operated to obtain the metals and halogens as such, or for chemical transpositions, and not "for the emplacement of the ions in such manner as to return by their recombination as kinetic energy the potentiality endowed by their disassociation by electrolysis." Salts, like chloride of calcium or sodium, or the nitrates of these metals are added in order to increase the conductivity of the electrolyte, without interfering in any way with the mechanism of the electrolytic action.

Accumulator Plate or Grid. J. von der Poppenburg, Charlottenburg, Germany. Patent 743,188, November 3, 1903. Application filed May 13, 1903.

The plate consists essentially of a grate-shaped current conductor, which comprises two straight longitudinal bars with a number of transverse bars. The central portion of the transverse bars, i. e., the portion comprised between the two straight longitudinal bars, is flat, while the projecting ends are slightly curved or bent. A frame is provided which has a series of recesses just opposite the free ends of the transverse bars. The grid is laid on the frame and the curved ends of the bars bent flat so that they slip into the recesses of the frame and thus firmly secure the grating to the frame. The active material is then applied to the frame in a suitable manner.

Battery Grid. G. H. Rabenalt, Buffalo. Patent 743,102, November 3, 1903. Application filed November 5, 1902.

The object of the invention is to arrange a grid in which the active material is securely held, and to maintain contact between the grid and the active material at all times regardless of the shrinking of the latter. The grid is therefore constructed of outside bars with a number of intermediate bars, so as to form a number of compartments. Each compartment is provided with an anchoring device relatively thin and constructed with projecting parts, which are intended to be imbedded in the active material. As the spongy lead shrinks and draws away from the outside bars or the cross-bars in the several compartments it contracts and closes tightly around the anchoring devices and is thus maintained in intimate electrical contact with them. Means are also provided for holding the marginal and corner portions of the active material intact and preventing their breaking off from the grid.

Secondary Battery. G. K. Hartung, New York. Patent 754,604, December 1, 1903. Application filed September 16, 1903.

The battery element described in the specification is composed of a series of tubes of porous earthenware, each tube containing the material to become active. The latter consists usually of an oxide of lead, mixed with resilient sub-divided inactive material, such as finely divided cork or pure rubber. The tubes are supported in a frame consisting of two strips which are clamped together and thus hold the tubes. In the center of each tube there is a rod of conducting material, the tubular elements being divided into two series alternating with each other, the rod of each series being connected to a metallic conductor. The tubular elements are thus divided into positive and negative elements. The compound element thus formed is immersed in an electrolyte, such as sulphuric acid and water and placed in an enclosing cell.

Storage Battery. Rufus N. Chamberlain, Depew, N. Y. Patent 746,289, December 8, 1903. Application filed May 13, 1901.

The invention relates to means for regulating the temperature of storage batteries, the object being attained by arranging a horizontal lead coil on the bottom of each cell below the electrodes, the coil being preferably separated from the bottom by a sheet of asbestos. Steam is used for heating the coil, and cold water is introduced for the purpose of cooling the contents of the cell whenever it is necessary. An insulated tubular coupling is interposed between the outlet pipe of one coil, and

the inlet pipe of the next following coil, for the purpose of allowing the heating or cooling medium to flow from one coil to the other without making a metallic connection between the coils.

Secondary Battery Separator. Hugh Rodman, Philadelphia. Patent 747,892, December 22, 1903. Application filed May 17, 1902.

The inventor has discovered that where wooden separators come in contact with the peroxide or active material of the positive plate the nascent oxygen causes deleterious rotting of the wood. The object of the invention is, therefore, to provide a wooden separator with ribs projecting from a central sheet, and to interpose a perforated sheet of rubber between the positive pole plate and the separator. The term "wooden" in the specification is intended to include also such materials as paper and other cellulose fiber products.

Galvanic Elements.

Galvanic Cell. W. Strickland, Brighton, England. Patent 742,365, October 27, 1903. Application filed July 23, 1903.

The invention relates to a cell which may be kept in an inactive state without deterioration and rendered active when it is desired to use it. It consists of a cylindrical receptacle, containing a carbon rod, surrounded by a mixture of manganese peroxide and Ceylon graphite, covered with several layers of a cotton material. The negative electrode is a cylindrical zinc plate, also surrounded on both sides by a layer of a similar cotton material. The upper part of the cell is filled with a dry powdered mixture of forty parts ammonium chloride, ten parts calcium chloride, five parts mercury sulphate, and twenty-five parts silver sand, all by weight. The whole is then covered with a layer of pitch, a vent hole closed by a stopper being left. When it is desired to render the element active this stopper is removed and water poured into the element.

Primary Battery.—J. A. Pedrazzi, Carmel, Cal. Patent 742,726, October 27, 1903. Application filed July 16, 1903.

The cell contains a zinc electrode, a porous cup and a copper electrode in a glass jar. The zinc electrode is formed of corrugated sheet zinc bent into cylindrical shape, the corrugations serving to hold the porous cup. The copper electrode is specially constructed, being built up of a number of parallel copper plates, upon which alternating layers of bare copper wire are wound, thus binding them all together. The exciting fluids are concentrated lye for the zinc electrode and sulphate of copper for the copper electrode.

Battery.—J. W. Gladstone, West Orange, N. J. Patent 742,857, November 3, 1903. Application filed September 17, 1903.

The invention relates to primary batteries and consists in a mechanical construction for the support of the negative electrode. The latter is held between two perforated clamps, which, by means of a locking device can be pressed tightly against it. In the element described the negative electrode consists of a plate of copper oxide. The positive zinc plates are supported from the cover of the cell, as is the clamping arrangement described above, and have the form of a U-shaped casting.

Battery.—J. W. Gladstone, West Orange, N. J. Patent 742,856, November 3, 1903. Application filed September 17, 1903.

The general arrangement of the cell is similar to the one described above, the mechanical construction for clamping the copper oxide plate being different.

Electric Battery.—H. Halsey. Patent 743,274, November 3, 1903. Application filed June 23, 1903.

The construction shown in this specification is practically identical with the one dscribed in the preceding specification.

Electric Battery.—H. Halsey. Patent 743,273, November 3, 1903. Application filed January 10, 1903.

This cell also contains a movable disc-shaped electrode, and a stationary electrode, the arrangement of the supporting mechanism being somewhat different than the one in the preceding constructions.

Electric Battery.—H. Halsey, New York. Patent 743,275, November 3, 1903. Application filed June 23, 1903.

This battery is another one of the inventor's type, with one or both movable electrodes. In this instance the movable electrode is mounted in hangers attached to the underside of the cover, the latter carrying suitable driving mechanism. The movable electrode is stated to be preferably composed of a number of parallel discs mounted on a shaft, and the fixed electrode preferably comprises a number of independent plates electrically connected to a binding post on the cover. A mechanical construction is described by which the several plates of the positive electrode can be readily removed for repairs.

Electric Battery.—E. Tweedy, New York. Patent 743,598, November 10, 1903. Application filed December 31, 1902.

The invention relates to two fluid cells, and especially to the arrangement of the diaphragm, in order to keep the latter rigid. The cell is composed of a number of frames, over the sides of which the diaphragms are tightly stretched and tacked. The upper openings of the frames are provided with covers, from which the electrodes depend. The negative element consists of a series of carbon rods. A desired number of sections may thus be built up, after which the assembled cell is placed in a box of larger size and the space between the two vessels filled with melted paraffine in order to make the arrangement fluid tight. Suitable provision is made for locking the covers tight in their position.

Battery.—G. Schauli and D. Lowenstein, London, England. Patent 743,337, November 3, 1903. Application filed July 14, 1903.

The invention relates to so-called dry batteries, of the carbon-zinc type. The cell consists of a containing vessel of tinplate, lined internally with a zinc layer. This containing vessel is separated from the zinc electrode proper by a cylinder of paraffined paper, canvas or like substance. The zinc electrode has the shape of a cylinder, closed at the bottom, and is filled with a pulpy exciting mass. The positive carbon electrode, surrounded by a depolarizing agent, is placed inside of the zinc cylinder in the exciting mass. The latter is prepared from rice, the operation of preparing the material consisting in first steeping it in water for one or several days, until a sufficient quantity of malt is formed, then boiling it with the addition of a little water down to a syrupy consistency, whereby, owing to the presence of the malt the greater part of the starch is stated to pass into grape sugar, and then adding salts which serve as electrolytes. It is claimed that the mass thus prepared is considerably less liable to fermentation and dessication than any of the organic substances hitherto employed.

Electric Battery. M. R. Hutchinson, Norwood, N. J. Patent 746,514, December 8, 1903. Application filed November 15, 1902.

The object of the invention is to provide a construction for sealing and venting batteries, whereby gases generated in the cell may have a free escape while the liquid is effectively replenished. The invention is especially applicable to cells which are intended to be carried on the person. A construction with these objects in view is described in detail in the specification.

Electric Battery. Sakizo Yai, Tokio, Japan. Patent 746,227, December 8, 1903. Application filed May 21, 1903.

The cell is composed of a casing made of zinc or lead plate, and a porous cylinder situated in the casing and preferably formed of blotting or similar paper. The annular space between the latter cylinder and the casing is filled with zinc oxide while the interior of the porous cylinder is filled with a mixture of manganese oxide and graphite powder. In the center of the latter is fixed a carbon or graphite rod. The cover of the casing is provided with an inlet-opening through which a solution of caustic potash is poured in.

MISCELLANEOUS.

Water Purifier.—O. M. R. Moeller, Copenhagen, Denmark. Patent 741,690, October 20, 1903. Application filed January 27, 1903.

The apparatus consists of a cylindrical vessel provided with a removable top adapted so as to be lightly clamped in position for the purpose of making a gaslight joint. The electrolytic part of the apparatus is located in the lower part of the cylinder and consists of a number of perforated metallic discs, alternately connected to the anode and cathode. The discs are separated from each other by insulating blocks, and they are separated from the walls of the cylinder by a cylinder of insulating material. The whole structure is so arranged that it can be easily raised and lowered if desirable. The electrolytic part of the apparatus is provided with a conical cover, the object being to collect the gases there. To further insure the action of the gasses liberated by electrolysis on the water to be purified, the upper part of the apparatus is provided with a series of perforated plates, the spaces between which are filled with crushed quartz, broken glass, and sand in the order named. The water enters at the bottom of the apparatus and passes out at the top, but the current can be reversed in order to effectually clean the apparatus.

Electrolytic Water Purifier.—G. W. Frazier, Allegheny, Pa. Patent 741,322, October 13, 1903. Application filed January 3, 1903.

The specification describes an apparatus consisting of a casing tube of glass or metal, which is closed by two circular heads with openings for the discharge and introduction of the water to be purified. The upper head also has two openings for the electrodes, which pass through insulating bushings. The electrodes consist of cylindrical metallic discs in contact with metallic cylinders. They are separated by a cross of an insulating material. The lower ring and the electrode resting on it are provided with a central passage, through which the water passes into the apparatus. It then flows outward between the arms of the insulating cross and rises around the upper electrode, finally leaving the apparatus by the outlet at the top. The lower electrode is stationary, but the upper one is furnished with a sliding contact, so that it can descend as it is consumed by electrochemical action. The inventor prefers to make the electrodes of aluminium and the contact discs and conductors of heavily silver-plated metal. The lower electrode is said to serve as anode usually, but an alternating current may also be used. The aluminium hydrate formed by electrolysis acts as a coagulating and purifying agent.

Ozonator.—J. Miller and F. M. Ashley, New York. Patent 742,341, October 27, 1903. Application filed December 19, 1902.

The invention has for its object the production of an apparatus in which ozone is generated by silent discharge. The silent discharge medium is a vial shaped body, preferably of glass, the closed end of which is covered with a thin metallic layer of tin-foil, amalgam or the like, and forms one electrode. The other electrode is constituted by a layer of similar material on the inside of the tube, which is extended out of the mouth of the latter and bent back so as to surround the mouth end on the outside. This vial-shaped body is suitably connected with the terminals of a circuit and enclosed in a containing vessel.

Sugar Making.—M. H. Miller, Wiarton, Canada. Patent 741,689. October 20, 1903. Application filed November 24, 1902.

The invention is stated to be especially applicable to the manufacture of sugar from beet juice and to the treatment of molasses. The process aims at effecting a most complete purification of the juices preparatory to the crystallization of the sugar. Among the apparatus devised for this purpose are two types of apparatus in which the juice is treated with an electric current in order to effect a separation of albuminous, foreign and coloring matter from it. The first apparatus consists essentially of a cylindrical tank, with a dish-shaped bottom in which a heating coil is disposed. A vertical shaft supported insulated in a step-bearing is placed in the center, and is surrounded by a hollow shaft. The hollow shaft has insulated openings, through which pass the arms of a vertical frame, provided with a number of vertical wires. The outer hollow shaft also carries a frame of the same dimensions, the wires on this frame, however, running horizontal instead of vertical. These frames are rotated by suitable means, and as the inner and outer shafts are connected with the respective terminals of a source of current, the frames are constituted electrodes. On account of this peculiar construction of the frames, the juice is brought into intimate contact with the electrodes, and the albuminous and other foreign matters are separated out. An apparatus of this construction serves for the first treatment of the juice. The second treatment is effected in an apparatus of similar cylindrical form, but without a heating coil. A large porous partition is arranged in the interior, the juice to be treated being placed inside the porous cup, while the outside of the cup is surrounded with water. A number of cylindrical iron cathodes are placed in the outer solution. The anodes inside of the porous cups are supported on a metallic sleeve, which is slipped over an insulating bushing, which, in its turn, is fastened upon a vertical metallic pipe, which serves to introduce the juice to be treated into the apparatus. Upon this sleeve are supported a number of pyramidal frames, preferably of lead or aluminium, the surface of each succeeding lower one being larger than that of the preceding upper one. The juice issues from the central pipe and gradually flowing down over the succeeding frames, is electrolyzed on its way down. The sleeve may also be moved up and down, so as to submerge or move the electrode, as desired. A whole installation of a sugar manufacturing plant, embodying these electric purification apparatus and the necessary filtering, pumping, etc., appliances, is illustrated in the specification.

Process of Sugar Making.—M. H. Miller, Wiarton, Canada. Patent 742,127, October 20, 1903. Application filed June 3, 1903.

In this patent the inventor protects the method of carrying out the making of sugar in apparatus described above.

Apparatus for Converting Oxygen Into Ozone.—F. S. Blackmarr and J. L. Willford, Minneapolis, Minn. Patent 743,432, November 10, 1903. Application filed April 26, 1902.

The apparatus described in the specification consists essentially of a long glass tube with open ends, which is provided on its outer surface with a number of metallic coils. On its inner surface it carries a number of longitudinal wires. Both sets of wires rest against the surface of the glass, and each of them forms one terminal of the secondary circuit of an induction coil. As the wires are in contact at all points with the tube, sparking is avoided and a "glow" produced around them. Oxygen or air is passed through the tube or along the wall, and thus into the field of the glow produced by the discharge of electricity from the wire. A fan is arranged which acts as an exhaust and draws a continuous stream of air through. Applications of the apparatus for inhaling the ozonized air, for connection with ventilating systems, storage outfits, bath cabinets and the ozonizing of water are described at length and illustrated in the specification.

Apparatus for Converting Oxygen Into Ozone.—F. S. Blackmarr and J. L. Wilford, Minneapolis, Minn. Patent 743,433, November 10, 1903. Application filed October 27, 1902.

The apparatus shown in this specification presents an improvement upon the one described above. It consists of a series of glass tubes, with narrow annular spaces between them. These tubes are preferably open at both ends, although the center tube may be closed at the bottom. The terminal of one pole of the induction coil is arranged upon the outside of

the outer tube, and consists of a spirally-wound wire. The intermediate electrodes consist of a series of thin corrugated metal plates, each of which, with its angles of corrugation is in contact with the inner surface of one tube, and the outer surface of the next. All the annular spaces between the tubes are filled in this manner. The innermost tube, which is preferably only open at one end, contains a terminal consisting of a suitably coiled wire. A controller and a cut-out are also provided, the latter serving to regulate the number of terminals which it is desired to have in the circuit, while the controller regulates the current through the terminals.

Method of Converting Oxygen Into Ozone.—F. S. Blackmarr and J. L. Wilford, Minneapolis, Minn. Patent 743,431, November 10, 1903. Application filed April 26, 1902.

This specification covers the process of operation with the apparatus described above, which consists in applying an interrupted electric current to the opposite sides of a wall formed of a dielectric substance, such as glass, mica, earthenware, lava, vulcanized rubber or any other suitable material.

Ozonizer.—Marius Otto, Paris, France. Patent 744,096, November 14, 1903. Application filed May 29, 1903.

The apparatus consists of a metallic cylinder, either bare or enclosed in a dielectric, which revolves around a vertical axis, and is connected with one pole of a high tension transformer, thus forming one electrode. The cylinder rotates within a thin glass tube, which, on the outside is covered with a metallic conducting layer, which is connected to the second pole of the transformer. Each of the electrodes is divided into portions separated along the generating lines of the cylindrical surfaces in order to avoid short-circuiting.

Correspondence.

CONTACT RESISTANCES AND CURRENT LEAKAGES IN AN ELECTROLYTIC COPPER REFINERY.

To the Editor of Electrochemical Industry:

Sir—Regarding Dr. Hutchinson's statements in your January issue I believe he is mistaken in assuming that there has been undue secrecy regarding electrolytic copper refining after the experimental stages were past.

Some electrolytic copper refineries built during the last five years have their power losses down to 10 per cent, or even less, and in 1899 it was appreciated that the plant under discussion could, with slight alterations, reduce its power loss by some 50 per cent, but other matters prohibited this change. There are plants operating now with only a 10 per cent loss, but these are not the cheapest plants to operate from a labor standpoint. Much good might come from experiments whose object is to decrease the power loss while not increasing the cost of labor beyond the power saved. B. Magnus.

Buffalo, N. Y.

AMERICAN ELECTROCHEMICAL SOCIETY ELECTION.

To the Editor of Electrochemical Industry:

Sir—Mr. C. J. Reed having announced to the Board of Directors of the American Electrochemical Society that he will not accept the duties of the secretaryship, or any other office in the Society to which he has been nominated for the next annual election, the undersigned wishes to announce through your journal that since some nominations have been received proposing that he act as secretary of the Society, in this emergency, that he is willing to serve the Society in any capacity in which the members think he can best aid it and promote its interests, and would take up the duties of secretary and fill them to the best of his ability if his fellow-members wish to elect him to that office.

Joseph W. Richards.

Bethlehem, Pa.

A BADGE FOR MEMBERS OF THE AMERICAN ELECTROCHEMICAL SOCIETY.

To the Editor of Electrochemical Industry:

Sir—Will you kindly allow me enough space in your valuable journal to call the attention of the members of the American Electrochemical Society to the fact, that, after over two years of organization, and several highly successful conventions, we are yet without any suitable pin or badge. I hope that the coming April convention will take this matter up and adopt one.

I would be glad to hear through your columns from some of the members on this subject.

W. A. McCoy.

Perth Amboy, N. J.

Current Notes.

American Electrochemical Society.—The following gentlemen were elected members of the American Electrochemical Society at the December meeting of the board of directors: Ross Phillips, Niagara Falls, N. Y.; H. P. Gibbs, Bangalore, India; Heinrich Paweck, Vienna, Austria; Gustave Gin, Paris, France; A. T. Smith, Liverpool, England; J. W. Turrentine, Easton, Pa.; F. L. Slocum, Pittsburg, Pa.; Laurent Lowenberg, Cincinnati, Ohio; J. F. Taylor, Cerro de Pasco, Peru; L. J. Lease, Urbana, Ill.; F. J. Pearson, Chicago, Ill.; Whitman Symmes, San Francisco, Cal.; Fausto Morani, Rome, Italy. At the January meeting of the board of directors the following gentlemen were elected: J. T. McNeier, Philadelphia, Pa.; Kenneth B. Quinan, Somerset, W. Cape Colony; G. L. Townsend, Washington, D. C.; Henry M. Loomis, Niagara Falls, N. Y.; Orion Brooks, San Francisco, Cal.; Charles A. Marie, Paris, France; P. L. T. Heroult, La Praz, France; G. Orth, Nancy, France; Fred. L. Shinn, Madison, Wis.; A. Gandillon, Geneve, Switzerland; A. Solvay, Brussels, Belgium; Louis A. Herdt, Montreal, Can.; William Stanley, Great Barrington, Mass.; Edwin J. Prindle, Washington, D. C.; H. M. Fernberger, Niagara Falls, N. Y.; Frederick Conlin, Bethlehem, Pa.; William L. Dudley, Nashville, Tenn.; Henry P. Talbo, Boston Mass.; Raymond Outwater, Washington, D. C.; Darragh de Lanley, Great Barrington, Mass.; E. R. Barrows, Brandt, Pa.; C. A. Little, Elyria Ohio. At the February meeting of the board of directors the following names will be presented: Archer E. Wheeler, Great Falls, Mont.; Frederick L. Wilder, Morro Velho, Brazil; H. H. Willard, Ann Arbor, Mich.; Murray C. Beebe, Pittsburg, Pa.; Edward Bennett, Pittsburg, Pa.; Frank C. Mathers, Bloomington, Ind.; F. W. MacMahon, London S. E., England; Charles Combes, Paris, France; Henry Carmichael, Boston, Mass.; Charles H. Dennison, Chelsea, Mass.; Gar. A. Roush, Broomington, Ind.

Philadelphia Section of the American Electrochemical Society—The first meeting of this section will be held in the Engineers' Club in Philadelphia, on February 5, the following papers being on the programme: Prof. J. W. Richards, on the electrolysis of mixed solutions; Mr. C. J. Reed, on the thermochemistry of the dissociation theory; Mr. P. G. Salom, on some recent experiments in storage batteries; Mr. Carl Hering, on a few constants in use in electrochemistry; Mr. S. S. Sadtler, on a subject to be announced at the meeting; Dr. Rudolf Gahl, on the theory of electromotive forces, and Mr. E. W. Smith, on the application of thermodynamics in the calculation of electromotive forces.

Manufacture of Achroodextrin and Alcohol.—According to a recent consular report the object of a process of Georges Reynaud, of Paris, relates to manufacturing industrially achroodextrin and alcohol. It consists essentially in soaking the material to be treated in twice its weight of water, and in

heating the resultant mass under pressure in an autoclave or digester at a temperature of 160° to 220° C. for about an hour and a half. Under the influence of this temperature, the cellulose and amylaceous constituents of the treated materials are converted into achroodextrin, which, by reason of its lower density, could advantageously replace ordinary dextrin in its industrial applications. Hitherto achroodextrin has only been known as a laboratory product, because the processes in vogue for the manufacture of dextrin always yield ordinary dextrin, or erythrodextrin. It is said that the new process does not necessitate the presence of any acid or other auxiliary substance, is most economical, and obviates the unavoidable defects connected with the employment of acids, the manipulation being convenient and presenting no danger. As soon as the conversion of the cellulose and amylaceous constituents into achroodextrin is completed, the aqueous solution is withdrawn from the apparatus, and may then be directly employed for industrial exploitation or submitted to a second operation for the purpose of converting it into alcohol. In the latter case, the aqueous solution is heated to 55° C. and then is added a pancreatic juice to produce saccharification, which is completed in about three hours. The liquid is then caused to ferment by the ordinary means, in employing yeast, care being taken to add two-thirds of 1 per cent of acid; when fermentation ceases the liquid is distilled in the usual way. This small quantity of acid may be introduced into the autoclave at the commencement of operations instead of during fermentation.

CLEANING SILVER.—In a daily paper we find a note that silver is easily kept bright if it is boiled occasionally in an aluminium kettle. This latter vessel must be kept perfectly clean and bright, and filled with hot water when the household silver is put in it. Keep the water boiling for fifteen minutes, then take out and dry the silver with the ordinary silver towels, and it will be found that the forks, spoons, etc., will be beautifully bright and glittering. The kettle, on the contrary, will have become tarnished. This note is of interest, since the action which takes place is entirely electrochemical. The tarnish on silver is either Ag_2S, Ag_2O, or a mixture of both, and the action on these by the voltaic couple formed with the aluminium is similar to Salom's manner of reducing galena, the Ag_2S or Ag_2O being cathode of the voltaic couple and the aluminium anode.

Book Reviews.

THE PROCEEDINGS OF THE CHEMICAL AND METALLURGICAL SOCIETY OF SOUTH AFRICA, Volume II. (February, 1897, to September, 1899). Johannesburg, Transvaal: Published by the Society; 928 pages. Illustrated. Price, $6.00.

The Chemical and Metallurgical Society of South Africa was founded in 1894, and was nick-named in its early days the "Cyanide Club," since its members were most intensely interested and engaged in the commercial development of the cyanide process. The second volume of the Transactions, which covers the time from February, 1897, to September, 1899, is full of very valuable practical information on the metallurgy of gold. In fact, it may be considered a complete history of the development of gold metallurgy on the Rand during the period mentioned. In view of its importance, we have abstracted those portions which refer to electrolytic precipitation methods, and present them in a separate article elsewhere in this issue. While by far the greatest part of the book has to do with the metallurgy of gold, yet it also contains some interesting papers on other subjects, among them a paper by Loevy on the constitution and effects of liquors (the liquor question being very important in South Africa), a paper by Prister on the manufacture of nitro-explosives, and a paper by Flower-Ellis on the Malay tin industry ("a far cry from Southern Asia to South Africa, from the land of tin to that of gold").

The volume is also highly interesting as a human document. It covers the proceedings of the time just preceding the war. The sturdy pioneers of metallurgical engineering which had come to South Africa from all parts of the world, were surely reigned by a very strong esprit de corps, although there seemed to develop somewhat like a professional jealousy between zinc precipitation and electrolytic precipitation advocates. At some places in the volume we find expressions of political dissatisfaction which indicate the coming war. But the book, as a whole, is a document of very good fellowship and some expressions of friendly sentiment are very touching. When Charles Butters, one of the pioneers of the electrolytic precipitation process in South Africa, left for the United States, Mr. Williams said that he did feel and know that Mr. Butters' name would be remembered and honored among chemists and metallurgists as long as the name of President Krueger and Cecil Rhodes would be remembered in politics.

We hope that the volume may find many readers among engineers and scientists interested either in the practice or theory of the cyanide process. As Mr. Butters says, somewhere in the volume, every one in the United States is intensely interested in the operations in South Africa, but a great deal of work is carried out in the United States laboratories that would be unnecessary if the published results of the practical work on the Rand were given greater circulation than at present. In this sense we hope that the abstracts from the volume, published elsewhere in this issue, on the electrometallurgy of gold, will be welcome to many of our readers, and at the same time we send our greetings to the Society beyond the seas, which now will soon celebrate the tenth anniversary of its formation, and we wish that its success in future may be even greater than in the past.

THE ART OF ILLUMINATION. By Louis Bell, Ph. D., New York: McGraw Publishing Company. 339 pages. Price $2.50.

The purpose which the author had in writing this book, and the object which he has most skillfully attained, was "to set forth some of the fundamental doctrines, optical, physiological and æsthetic, which underlie the proper use of artificial illuminants, and to point out how they may be advantageously adapted to existing conditions."

The scope of the work may be best judged from the headings of the various chapters, viz., light and the eye, principles of color, reflection and diffusion, illuminants of combustion, incandescent burners, the electric incandescent lamp, the electric arc lamp, shades and reflectors, domestic illumination, lighting large interiors, street and exterior illumination, decorative and scenic illumination, standards of light and photometry, the illumination of the future.

As regards the manner of treatment, it may truly be said that the author unites the accuracy of a scientist with the perceptions of an artist. The work is not mathematical nor severely scientific, yet it is scientifically accurate; it is not a refined philosophical or psychological essay on the perceptions of color or the physiological effect of light, yet it is philosophical and artistically pleasing in a manner within the range and capacity of every educated reader.

About the only criticism we would venture is that the industrial value of acetylene is not properly appreciated. The author hardly gives this gas the full credit which its present use bespeaks, and certainly does not fully gauge the possibilities of cheaper acetylene. A large proportion of the extent of even the most civilized countries is entirely outside of the range of municipal gas supply, and a considerable proportion outside of the range of electrical illumination, and for all such areas acetylene is probably the coming illuminant, whenever anything more brilliant than the kerosene lamp is desired. Incidentally, this means a still greater extension of one of the largest of the electrochemical industries.

Dr. Bell's book may be recommended not only to the professional "illuminator," or architect, or physicist, as a book which they should all "read, mark, learn and inwardly digest," but we would cordially recommend its perusal to everybody who has need of illumination of any kind, and who wishes to know how best to choose and to use it.

Die Electrochemie und Metallurgie auf der Industrie und Gewerbe Ausstellung in Duesseldorf, 1902. By H. Danneel. Halle a. S.: W. Knapp. Price $2.00.

This book is amplified from an article by the author in the *Zeitschrift für Elektrochemie*. It describes the varied exhibits at the late exposition in the hustling German town of Duesseldorf.

Electrochemists in general will be interested in the descriptions of the various electrochemical products and processes, such as Elmore's, that of calcium carbide, etc. The description of the electrical measuring instruments, electric furnaces and pyrometers can be recommended.

ELECTROLYTIC RECTIFIER AND INTERRUPTER.

For several years attempts have been made to utilize for practical purposes the well-known property of an aluminium electrode to permit a current to pass freely in one direction, and to offer a strong resistance to its flow in the opposite direction. This property seems to have been first discovered by Wheatstone in 1855, and has long been the object of investigations made with a view of utilizing it for the design of an electrolytic rectifier.

In the first attempts a single cell was used, with one aluminium electrode, the other electrode being of another suitable metal. If an alternating current is impressed on such a cell, it should allow only one-half of each wave of the alternating current to pass, and a uni-directional (although pulsating) current would be obtained. In reality, however, the aluminium anode is not a perfect valve, since it allows a small leakage current to pass, so that a single cell of the above description does not give a uni-directional current, but an alternating current, although with one alternation of greater amplitude than the other. The practical result in charging a storage battery is that the efficiency is low. The battery is correctly charged during one-half wave, but is somewhat (although not fully) discharged again by the next half-wave. The efficiency is therefore generally not more than 20 per cent.

The next step in the development of the rectifier was made by Graetz, who used a combination of four rectifying cells, and really obtained a true uni-directional current. But the efficiency was low, and the combination complicated.

In the Churcher rectifier, built by the Electric Appliance Co., of Cincinnati, Ohio, a single cell is used, and a high efficiency is claimed for its operation. There is a small leakage current, but it does not pass through the apparatus operated by direct current, and would therefore not discharge a battery that is to be charged, but is expended in heating the solution. This loss depends largely upon the initial formation of the oxide film of the aluminium, the purity of the aluminium, and the solution, and on the temperature which should not become too high. Where continuous service is required of the rectifier, it is desirable to prevent the rise of temperature by a method of water-cooling.

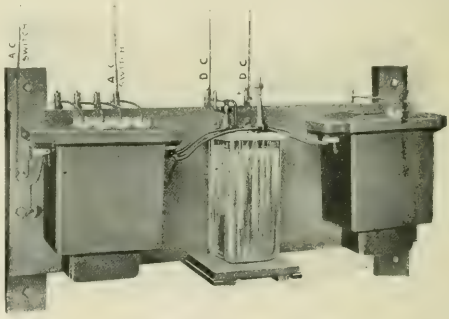
The Churcher rectifier is used in connection with a transformer, the secondary of which is designed for twice the direct-current voltage required plus the resistance loss. This secondary coil is tapped in the center, and by virtue of the action of the rectifier this tap remains positive at all times.

Each of the two terminals of the secondary coil is connected with an aluminium electrode in the rectifier. Owing to the film on either of these electrodes no appreciable current passes between them (otherwise the transformer would be short-circuited). Between these active electrodes, but insulated from them, is placed an inactive electrode of platinum, and between the latter and the center tap of the secondary of the transformer, there is connected the battery to be charged or the direct-current motor or the electrolytic or plating cell to be operated.

During operation the current passes from the center tap of the transformer to the battery to be charged, then to the platinum electrode in the rectifier (which is therefore always anode) and from it to one or the other aluminium electrode according to which is at that instant negative to the center of the transformer. It will thus be seen that one side of the transformer is active, while the other is inactive, and then reversed during the next alternation.

The regulation of the direct current is best attained by placing an adjustable inductance between the transformer terminals and the aluminium electrodes of the rectifier, or it may be accomplished by an inductance in the main alternating supply, or by varying the number of turns in the primary of the transformer. This form of regulation is much more efficient than placing resistance in series with storage batteries when charging from 110-volt direct-current mains. The latter method is, of course, simply a waste of energy.

That the uni-directional current which passes through the battery is pulsating, is considered an advantage, since it is claimed to have been found in practice that a pulsating uni-



ELECTROLYTIC RECTIFIER

directional current is better for charging a battery than a perfectly uniform continuous current.

By the use of two cells and two secondaries in the one transformer, twice the voltage may be obtained. By using three cells with three secondaries in the one transformer, three times the voltage is produced, etc. It is thus quite clear that the regulation is very easy.

The adjoining illustration shows a 50-volt rectifier, with a capacity of 20 amperes. The Electric Appliance Co. builds rectifiers for the following capacities: Fifty volts, and 10 or 20 amperes; 70 volts, and 30 amperes; 100 volts, and 20 amperes, and smaller ones for 25 volts, and 1 or 2 amperes, and 50 volts, and 2 amperes.

While the charging of storage batteries from alternating-current mains is probably the main industrial application at present, yet there should be a wide field for a reliable rectifier in electrochemistry in all such cases where only alternating current is available, and direct current is required for electrolytic purpose. The above information is taken from an interesting paper presented by Mr. W. B. Churcher to the Northwestern Electrical Association at Milwaukee.

VACUUM DRYING APPARATUS.

The process of evaporating liquids in vacuo has long been practiced, on account of its many advantages, among which may be mentioned the great saving in time, the feasibility of reclaiming valuable solvents, the control of noxious vapors,

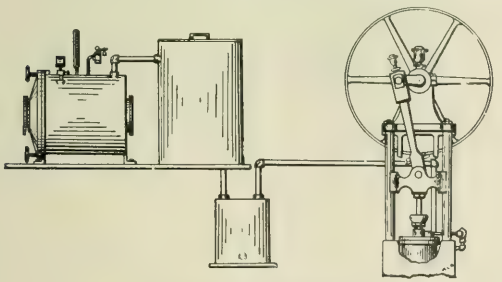
and the increased quantity and superior quality of the product due to the lower temperature at which the process may be carried on, and to the exclusion of air during the operation. For many substances which, on account of their nature, must be dried at a low temperature, drying in vacuo is in especially extended use.

There are at least three different methods and types of apparatus employed in the vacuum process, namely: first, the vacuum pan method, for the concentration of liquids, in which a pan, a jet condenser, and a vacuum pump are used, and in which method the condensed vapors are discharged simultaneously with the condensation water, and are not recovered. This is known as the "wet system" of working in vacuo. Secondly, the vacuum still method, in which are used a closed pan, a surface condenser, a receiver of the distilled solvent, and a vacuum pump. Thirdly, the vacuum dryer method, consisting of a vacuum chamber, a surface condenser, a vacuum pump, and a receiver of the solvent if it is to be reclaimed.

The apparatus built by the American Vacuum Drying Machine Co., of New York City, one type of which is shown in the adjoining illustration, employs the features of the third method, drying the material in a very short time, and, if desired, recovering in the same operation the valuable solvents, such as alcohol, ether, etc.

The temperature in the drying chamber can be regulated with precision, oxidation with its detrimental effects is altogether avoided, noxious fumes are harmlessly discharged at any desired point, and the material treated by this process is of very uniform quality.

The stationary American Vacuum Drying Machine proper consists of a cylindrical or rectangular chamber, within which are placed, at suitable distances apart, hollow metal shelves, through which either direct steam at low pressure, exhaust



VACUUM DRYING APPARATUS.

steam or hot water, is circulated; or, if steam at high pressure is to be utilized, coils of pipe, arranged to serve as shelves, are employed.

The pans or trays containing the material to be dried are placed on the heated shelves, after which the hinged and air-tight doors are closed, whereupon the air and vapors are withdrawn from the drying chamber by means of the condensing apparatus, and, if it is desired to reclaim valuable solvents in the same operation, a receiver is connected with the surface condenser or with the pump.

When, however, it is necessary to meet the requirements of any particular shape of materials to be dried, and to which the above-mentioned shelves may not be adapted, other suitable interior arrangements may, of course, be used in place of such shelves; for instance, vacuum tunnels, in which suitable cars are operated on a track so that the largest quantities can be handled.

The C. W. Hunt Co., of West New Brighton, N. Y., have issued a very neatly illustrated pamphlet on "industrial" narrow-gauge railways, which gives much valuable information on this subject.

GENERATORS FOR ELECTROPLATING, ELECTROTYPING AND OTHER ELECTROLYTIC WORK.

On pages 40 and 296 of Vol. I. we have described in detail the construction of the "Eddy" machines for electroplating, electrotyping and other electrolytic work, which are now being manufactured by the General Electric Co. From bulletin 4350 of this company we gather the following additional information on the use of these machines for plating work. While it contains nothing of special novelty, yet the information is given in such a simple form as to be readily understood by every practical electroplater.

When the anode in an electroplating tank is of the same metal as that with which it is desired to coat the cathode, no voltage would be required to do the plating, were it not for the resistance of the solution. The e. m. f. required at the terminals of a plating vat must be slightly above that for overcoming the internal resistance of the cell, and depends, therefore, on the nature of the solution, its temperature, the surface exposed by both anode and cathode, the distance between them, and the current density per unit of plate area (amperes per square foot).

If the anode is made of a material unaffected by the solution, then the voltage required will be that needed to overcome the resistance, plus that necessary to break up the metal-carrying compound in solution (for $CuSO_4$ — 1.21 volts, $PbSO_4$ — 1.61 volts, etc.) and in this case the metal-carrying compound must be added to the solution when necessary, as otherwise the plating would soon cease, owing to the absence of metal.

While it is true that a certain number of ampere hours will always reduce the same amount of metal from a given solution, the electroplater desires the deposited coating to be more or less reguline, and it has been found that in order to obtain a suitable deposit it is necessary to limit the number of amperes per square foot of cathode surface, or the rate of deposition. The rate of deposition for a given grade of coating has been found to be considerably affected, in many cases, by the temperature at which the solution is used, and may be largely increased by giving motion to the cathode or agitating the solution. There are many solutions from which no satisfactory deposits can be obtained, and some solutions cannot be used with certain cathodes, for example, $CuSO_4$ cannot be used with cathodes of Fe and Zn.

Theoretical efficiency, both with regard to voltage required and output per ampere hour, is seldom obtained outside of the laboratory, due to impurities, secondary reactions, polarization, etc., but in most cases these troubles are of minor importance and considerably more than 95 per cent of the theoretical amount of metal per ampere hour is often obtained in ordinary practice.

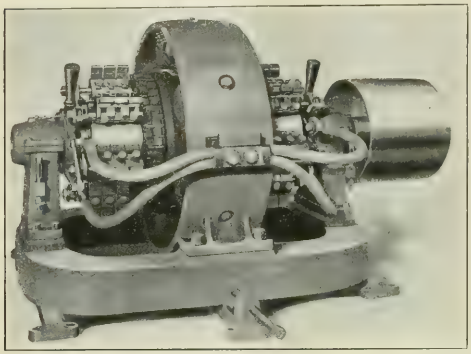
The old practice of rating electroplating machines by the number of gallons of certain solutions they could supply with current, is not only inaccurate, but very misleading, as the current required for a given volume of solution depends on the cathode surface exposed to it, and the permissible current density. It varies, therefore, with the size and form of the objects to be plated, and the grade of deposit desired. One grade of work may require two or three times as much solution for the same amount of deposit as another grade.

If the machines be rated in amperes there should be no doubt as to what is meant, as a given number of ampere hours will deposit a certain weight of metal, or will cover a certain number of square feet of cathode surface with a given thickness of film.

One thousand ampere hours, when used in a suitable bath, will theoretically deposit approximately the folloying weights of metals:

Cu (copper)	41.8	oz.	Avoir
Ni (nickel)	38.6	"	"
Brass	42	"	"
Zn (zinc)	43	"	"
Ag (silver)	129	"	Troy
Au (gold)	78.8	"	"

The following table gives the theoretical rates of deposition per hour, at full load, for the different machines, but if two or more tanks are used in series, the amount will be found by

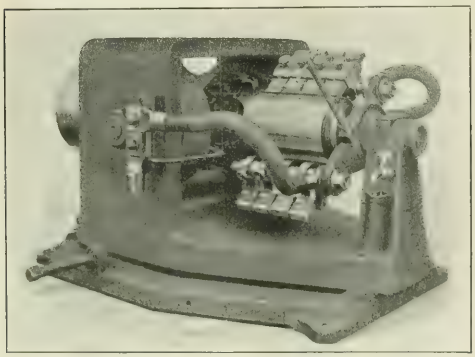


ELECTROPLATING DYNAMO, 6 TO 12 VOLTS, 2000 TO 1000 AMPERES.

multiplying that given below by the number of tanks in series. The actual rate will, in most cases, be slightly less.

Amperes.	Oz. Avoir. Per Hour.				Oz. Troy Per Hour.	
	Copper.	Nickel.	Brass.	Zinc.	Silver.	Gold.
150	6.25	5.75	6.3	6.4	19.4	11.8
300	12.5	11.5	12.6	12.9	38.3	23.6
600	25.1	23.1	25.2	25.8	77.6	47.3
900	37.6	34.7	37.8	38.7	116	71
1000	41.8	38.6	42	43	129.4	78.8
1500	62.8	57.9	63	64.5	194	118.2
2000	83.6	77.2	84	86	258.8	157.6
2500	104.6	96.5	105	107.5	323.4	197

96,538.5 coulombs is given as the ionic charge per univalent gramion, or practically 96,540, and even if the name and meaning of this constant should be considered of little value to the practical electroplater, the constant itself may be used by them to considerable advantage. Let a equal the chemical equivalent of any element; that is, its atomic weight divided by its valency, or combining power, then, $a \times 3600 \div 96{,}540$



ELECTROPLATING DYNAMO, 5 VOLT, 150 AMP.

grams of the element are liberated per ampere hour, and $96{,}540 \div (3600\ a)$ ampere hours are required to liberate one gram.

1 oz. Avoir. = 28.35 grams; 1 oz. Troy = 31.1 grams.

Dividing the result obtained from the first equation by the grams per oz. will give the ounces per ampere hour, and multiplying the result obtained from the second equation by the grams per oz. will give the ampere hours required per oz.

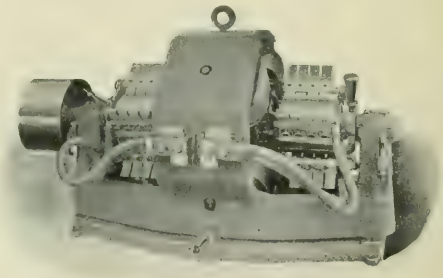
For example, the atomic weight of silver is 107.93 (Hering), valency 1, and therefore chemical equivalent 107.93. From $107.93 \times 3600 \div 96{,}540$ we get 4.025 grams per ampere hour. This, divided by 31.1 = 0.1294 oz. Troy per ampere hour, or 129.4 oz. Troy per 1000 ampere hours.

As the voltage required for plating with like anodes is independent of the metal deposited, and is determined by the resistance of the solution, etc., the determining conditions being so variable we should expect a large variation in the voltages used, and this is found to be the case.

The following, however, gives the ordinary limits in actual use:

Copper sulphate	0.2	to	2	volts
Copper cyanide	2	"	5	"
Nickel	1	"	6	"
Brass	2	"	6	"
Silver	0.3	"	1	"
Gold	0.5	"	3	"

The rate of deposition, or amperes per square foot of cathode surface used, also varies largely, depending on the grade



ELECTROPLATING DYNAMO, 5 TO 10 VOLTS, 600 TO 300 AMP.

of deposit desired, the nature of the solution, its temperature and whether it is used still or agitated. In fact, a rate as high as 500 amperes per square foot has been used with copper, and a reguline deposit obtained under proper conditions. (Mailloux.)

The following are the rates in ordinary use:

Copper sulphate	2	to 150	amps. per	sq. ft.
Copper cyanide	3	" 40	" "	"
Nickel	1	" 30	" "	"
Brass	3	" 20	" "	"
Zinc	2	" 18	" "	"
Silver	1	" 10	" "	"
Gold	1	" 8	" "	"

Electrorefining is practically electroplating, the metal to be refined being used in its impure state as the anode, and such a solution used that all the impurities are either held in suspension, or fall to the bottom, and only the pure metal is deposited on the cathode.

PERSONAL.

Mr. E. Stütz delivered a lecture on aluminothermics before the Franklin Institute, of Philadelphia, on January 20, and will deliver another lecture before the Boston Section of the American Chemical Society at the Massachusetts Institute of Technology on February 25.

On December 19, 1903, the twenty-fifth anniversary of the day on which Prof. WILHELM OSTWALD received the degree of Ph. D., with his thesis "Volum-chemische und optisch-chemische Studien," was celebrated in Leipzig. Among the speakers who presented their congratulations to the famous scientist were Van't Hoff, Walden, Trey, Wagner, Landolt, LeBlanc, von Oettingen, Stein (who spoke of Ostwald as philosopher), Lepsius and Arrhenius. Congratulatory telegrams were received from all parts of the world, among them from the following cities in America: Ann Arbor, Mich.; Baltimore, Berkeley, Cal.; Ithaca, N. Y., and Toronto, Canada. Van't Hoff presented the Ostwald "Jubelband," a large volume containing papers from many former students of Ostwald.

INDUSTRIAL NOTES

INSULATORS.—We have received from Mr. C. S. Knowles, Boston, catalogue 20, on glass and porcelain insulators.

PAINTS.—We have received from Mr. A. Grothwell, San Francisco, an illustrated booklet on the various uses of his "Mogul" paint.

The LAIDLAW-DUNN-GORDON Co., of Cincinnati, have sent us bulletin L-509 on Meyer gear air compressors, with rolling-mill frames.

Messrs. SAUVEUR & WHITING, of Boston, Mass., announce that they are now prepared to give an elementary course in metallography by correspondence.

We have received from Messrs. S. B. CONDIT, JR., & Co., of Boston, their bulletin C-22, on Elder automatic circuit breakers, single pole, direct and alternating current.

MOTOR-VEHICLES.—Circular 1059 of the Westinghouse Electric & Manufacturing Co. deals with electric motor-vehicle equipments. Illustrated descriptions are given of automobile motors, controllers, and accessories, like battery indicators, charging receptacle, battery contacts, etc.

ELECTROLYTIC GENERATORS.—Bulletin 4,350, of the GENERAL ELECTRIC Co., deals with generators for electroplating and electrotyping and other electrolytic work, which were already described on page 40 (Eddy Manufacturing Co.) and page 296 of Vol. I. of this journal. Some interesting details given in the bulletin will be referred to in our next issue.

Bulletin 1049 of the Fort Wayne Electric Works gives a list of plants operating types MP and MPL, direct-connected, direct-current generators. Bulletin 1050 gives a description of direct-connected type MPL, direct-current generators for power and lighting. Bulletin 1051 gives a list of plants operating single-phase alternators in the United States.

We have received from MESSRS. QUEEN & Co., INC., of Philadelphia, their neatly illustrated pamphlet with the title "Fifty Years, 1853-1903." The firm was established by James W. Queen, in 1853. The pamphlet contains illustrated notes on the firm's optical, mathematical, engineering, microscopical, physical, electrical, meteorological, astronomical, photographic and chemical departments and factories.

SUCTION PRODUCER GAS FOR POWER.—The S. R. Smythe Co., of Pittsburg, Pa., represented in New York by Dr. Oskar Nagel, has issued a catalogue on Suction Gas Producers for Gas Engines, showing the simplicity and advantages of the construction and the economy in fuel attained thereby. These producers are built in units from 5 to 150 hp., and are stated to yield 1 hp. hour per pound of coal. No boiler or gasholder is required.

ASBESTOS THEATER CURTAINS.—The H. W. Johns-Manville Co., of New York City, have sent us a pamphlet on asbestos theater curtains, with some samples of asbestos cloth. The theater curtains made by this company are pure asbestos, interwoven with brass wire, to produce sufficient tensile strength. It is suggested that the major part of the scenery on the stage, as well as all the upholstery and carpets, could be made of asbestos cloth, thus diminishing the dangers of theater fires very considerably.

NIAGRITE.—A material for preventing loss by fire, and danger to life from the short-circuiting of high-voltage electrical wires, for which the trade-mark "Niagrite" has been adopted, is being placed upon the market by the H. W. Johns-Manville Co., of New York City. "Niagrite" is furnished in strips of several widths, from 3 inches to 36 inches, and is held in place by asbestos fireproof glue, thus protecting the cables from external fire and confining the internal fire. The material presents a very neat and permanent finish, and is not affected by atmospheric conditions.

AIR COMPRESSORS.—A new line of air compressors is described in bulletin L-509, recently issued by the Laidlaw-Dunn-Gordon Co., of New York City. These compressors are fitted with Meyer steam-valve gears, permitting of an adjustable cut-off. The air ends are arranged both with poppet inlet and outlet valves, and with mechanically operated inlet and poppet outlet valves, the valves in either case being placed in the head of the cylinder, permitting the body to be effectively water-jacketed. The frames of the compressors are specially heavy. The capacities listed range from 468 to 2220 cubic feet of free air per minute, and the air pressures from 80 to 100 pounds per square inch.

ALUMINOTHERMICS.—Mr. E. Stütz, of New York City, who represents in this country, the thermit process, controlled by the chemical and tin smelting works of Th. Goldschmidt, Essen-Ruhr, Germany, announces that he is now in a position to supply thermit and appliances such as crucibles, etc., from stock in New York. A number of pamphlets have been prepared, giving instructions in a concise form. The great interest aroused by Dr. Goldschmidt's lectures of last year has rendered necessary the import of thermit and accessories from Germany, until the preparations have been completed for manufacture in this country. The offices of Mr. E. Stütz have been transferred to Wall Street Exchange Building, 43-47 Exchange Place, New York City.

ELECTRIC LIGHTING OF RAILWAY CARS BY STORAGE BATTERIES.—Catalogue 110, of the DAYTON MANUFACTURING Co., of Dayton, Ohio, deals with the use of the Silvey storage battery for lighting railway cars. The Silvey system is extremely simple, every variety of automatic devices being left out. No dynamos are carried on the train. The entire apparatus consists of storage batteries, 24-volt, 2.5-watt lamps, and the switch for turning on of the current. Each car is provided with its own individual battery, and its lighting system is an entirely independent unit. The batteries are charged at the terminals of the road, when it does not exceed 2,000 miles in length, since the battery on the car provides sufficient current for a run of 2,000 miles without any attention. The catalogue contains a great many extremely pretty half-tones.

THE LOOMIS-PETTIBONE GAS MACHINERY Co., has been merged with the Holthoff Machinery Co., of Milwaukee, under the new coporation name of Power and Mining Machinery Co. Extensive improvements and additions are made to the Milwaukee plant for the manufacture of the American Crossley gas engines, Loomis-Pettibone gas apparatus, and Holthoff mining metallurgical machinery. We have received from this company their pamphlet on gas for furnace work. By their system bituminous or anthracite coal, coke or wood can be burned. Some figures are given to show a saving of over a hundred per cent with the use of gas fired furnaces over that of oil fired furnaces. A fixed clean gas is produced, that can be conveyed over desired distances through cast or wrought iron pipes, thus obviating the necessity of numerous small coal piles scattered throughout the works. Some notes are given on the new plant of the Pennsylvania Steel Co., at Steelton, Pa.

Pelton Wheels.—A large order for Pelton water-wheels is being completed for the Columbia Improvement Company, near Tacoma, Wash. The installation consists of four Pelton units, aggregating 31,000 hp., operating under an 850-ft. head. These are the largest water-wheel units in the world, with the exception of those at Niagara Falls.

DIGEST OF U. S. PATENTS

Prior to July, 1902.

Compiled by Byrnes & Townsend,
Patent Lawyers,
National Union Building, Washington, D. C.

634,271. October 3, 1899. Henri Plater-Syberg, Paris, France.

Method of making acetic acid. An alkali acetate is produced by digestion of wood or moss rich in carbohydrates in hot concentrated alkali solution with injection of air. The resulting crude acetate is electrolyzed in diaphragm cell with anode and cathode of iron, yielding at the anode ferrous acetate and at the cathode the hydrate of the alkali. The ferrous acetate is dried, pulverized and oxidized by air to ferric acetate, which is decomposed with neutral alkali acetate, whereby the iron is precipitated as hydrate and the biacetate of the alkali is formed. This biacetate separates on heating into acetic acid and neutral acetate. The cathode lye is employed for digestion of fresh quantities of wood.

644,050. February 27, 1900. Hermann Beckmann, Witten, Germany.

Lead peroxide is formed by the anodic oxidation of lead in a solution containing free suphurous acid. Is applied mainly to the formation of Planté plates, the advantage being that no substances detrimental to the duration of the electrodes are employed.

651,396. June 12, 1900. E. A. G. Street, Paris, France.

Chromium hydroxide is produced by the electrolysis of chromate or bichromate solutions with a cathode of mercury, preferably at a temperature of 70° C. It is stated that the formation of the chromic hydroxide depends upon the presence of metallic sodium, as sodium amalgam. A platinum anode may be used, or the anode may be of mercury; in the latter case insoluble mercury chromate is formed on the anode and may be transformed into chromic hydroxide and mercury by reversal of the current.

650,536. May 29, 1900. Arthur Hough, San Francisco, Cal.

Mannite is produced by electrolytic reduction of glucose solutions. A diaphragm cell is preferably, but not necessarily used, the anode compartment containing water, and the cathode compartment the glucose solution. The mannite is produced directly by addition of hydrogen, and may be recovered from the solution by evaporation. Reference is made to the previous method involving the use of sodium amalgam.

662,585. November 27, 1900. George H. Benjamin, New York, N. Y.

Produces diethyl-ether by the joint action of ethylene, hydrogen and oxygen, on hydrogen-ethyl sulphate. The method is electrolytic only in that the hydrogen and oxygen are preferably produced by electrolysis of water in presence of the remaining compounds.

665,244. January 1, 1901. Paul Magnier, Billancourt, France.

Sponifies fatty substances, such as tallow, oils, vegetable butter and oleic acid. To the fatty substance liquid or liquefied by dissolving it in oleic acid or oil, is slowly added sulphuric acid, the liquid being continuously stirred, and the mixture is allowed to stand for a few hours. The amount of sulphuric acid required may be reduced from 50 to 10 or 12 per cent by adding it drop by drop, and to 6 per cent by simultaneously heating the fatty body to 80° C. To the product is added five or six times its weight of hot water, and the resulting emulsion is introduced into a metallic digesting vessel, which serves as an electrode, another electrode of carbon being suspended therein. The digester is closed and heated to a temperature sufficient to create an internal pressure of from three to five kilograms per square centimeter. An electric current is then passed through the mass, until the saponification is complete. The fatty acids float to the surface, while the glycerine and sulphuric acid remain dissolved in the mother-lye. Any free oleic acid added to or present in the emulsion is largely converted into solid fatty acids. The magma is removed and subjected to the usual treatment for the manufacture of stearin.

665,783. January 8, 1901. Henry K. Hess, Philadelphia, Pa.

Regenerates the spent liquids of two-fluid batteries containing respectively chromium sulphate and zinc sulphate. The chromium sulphate solution is placed in porous cups containing the anodes, which may be granulated lead filling the cups. corrugated sheet lead, graphite or platinum. The cups are placed in a vessel containing the zinc solution. A vertical series of trays containing mercury, serving as cathodes, are placed in the zinc solution; or amalgamated copper-plate cathodes may be used. The electric current reoxidizes the chromium solution to chromic and sulphuric acid and the zinc is deposited in the mercury or on the copper plates.

670,201. March 19, 1901. Edward D. Kendall, Brooklyn, N. Y.

Produces zinc oxide and sodium nitrite by electrolyzing a saturated solution of Chili saltpeter, employing anodes of zinc and cathodes of copper, iron, tin-plate or lead. The vessel may serve as cathode. Potential difference 6 volts. The zinc oxide separates from the anode and precipitate to the bottom of the vessel, where it is collected in a tray.

679,985. August 6, 1901. Hippolyte Palas and Felix Cotta, Marseilles, France.

Produces copper sulphate and caustic alkali in a cell having double diaphragms, consisting of two spaced asbestos sheets, which are externally supported by wood or glass grids. The cell is built up of rectangular wooden frames, having but three sides, between which the diaphrgms are clamped. The anodes are of copper or other metal whose sulphate is desired, in the form of plates, strips, waste, chips, ores, or copper pyrites residues. The cathods are iron plates. A copper sulphate solution is placed in the anode compartment and an alkali sulphate solution in the cathode and diaphragm compartments. The alkali solution is continuously introduced into the diaphragms, maintaining therein a slight head, which causes a circulation through the diaphragm walls and prevents oxides from being precipitated therein. Potential difference, 2.5 to 3 volts.

680,543. August 13, 1901. Wilhelm Pip, Darmstadt, Germany.

Refers to an unsuccessful prior attempt to produce piperidin from pyridin by electrolyzing a solution of ten parts of pyridin in 100 parts of 10 per cent sulphuric acid, using lead cathodes. Renders the process successful by employing pure acid, and at least three equivalents of acid to one of pyridin, using electrodes of lead, carbon, mercury or silver. Hydrochloric acid may be substituted for sulphuric. Example: 10 kilograms of pyridin are dissolved in 110 kilograms of water and 25 kilograms of 65° Be. sulphuric acid and placed in the cathode compartment of a diaphragm cell having both electrodes of lead. The anode compartment is filled with a solution of 5 kilograms of 66° Be. sulphuric acid in 50 kilograms of water. If clay diaphragms are used, they should be free from easily-decomposable iron silicates or other soluble salts, carbonates, etc. A less advantageous method consists in electrolyzing the same pyridin solution in a cell without diaphragm. In either case, the preferred cathode current density is 4.5 amperes per square decimeter.

Electrochemical Industry

VOL. II. NEW YORK, MARCH 1, 1904. NO. 3.

Electrochemical Industry

Published on the first of each month by the
ELECTROCHEMICAL PUBLISHING COMPANY,
[*Incorporated.*]
114-118 LIBERTY STREET, NEW YORK.

J. W. RICHARDS, PH. D. ..... *President.*
E. F. ROEBER, PH. D. ..... *Editor.*

Telephone Call: 7607 Cortlandt.

Subscription Price: $2 per year, postpaid to any part of the world. Single copies 25 cents.

ADVERTISING RATES GIVEN ON APPLICATION.

Copyrighted, 1904, by the Electrochemical Publishing Co.

Entered as Second-Class Matter, June, 1903, at the Post-Office at New York, N. Y., under the Act of Congress, March 3, 1879.

CONTENTS.

Editorial 81
Electroplating upon Aluminium. By Charles F. Burgess and Carl Hambuechen 85
What Ailed the Dynamo? By D. H. Browne..... 86
A Laboratory Study of the Stages in the Refining of Copper. By H. O. Hofman, C. F. Green and R. B. Yerxa..... 87
Philadelphia Section of the American Electrochemical Society.... 95
Structure and Tension. By Oskar Nagel..... 97
The Theory of Electrode Potential. By W. McA. Johnson..... 97
The Cyanide Plant and Practice at the Ymir Mill. By E. C. Holden 101
Pioneers of Electrochemistry—VII: T. A. Edison..... 103
The Power Plant of the Moctezuma Copper Company at Nacozari, Sonora, Mexico 104
Notes on the Limitations of the Cyanide Process. By H. T. Durant 107
Analysis of Current Electrochemical Patents. By Geo. P. Scholl.. 108
Synopsis of Articles in Other Journals..... 114
Correspondence: Mercury Cathode Cell. By A. E. Truesdell..... 119
American Electrochemical Society Election. By H. S. Carhart. 119
Book Reviews 119
Current Notes 120
The Use of Caustic Potash in Electroplating Shops..... 121
Ferro-Silicon Made in the Electric Furnace..... 122
Meteorit 122
Industrial Notes 123
Personal 123
Digest of U. S. Patents, Prior to July, 1902. By Byrnes & Townsend 123

PLATING UPON ALUMINIUM.

Electroplaters have long been largely interested in attempts at coating aluminium with other metals, there being a growing demand especially for gold and silver plating upon certain aluminium objects, such as toilet articles, ornaments, etc. But the difficulties of the problem are well known. While it is easy to get a metallic deposit upon aluminium, it is generally still easier to remove this deposit again by simple pressure. By certain precautions it is possible to get a deposit which will stand the buffing or polishing operations; but even in these cases, the coating is generally loosened afterwards when the article is in daily use, especially when exposed to moisture. The reason why the coating will not stick is that the metal of the coating is not intimately alloyed with the aluminium surface beneath. Zinc is a metal which alloys well with aluminium. Nevertheless, a zinc coating applied to an aluminium surface, under ordinary conditions, will not stick, because the aluminium surface was not aluminium, but coated with that well-known invisible oxide film which gives to aluminium such peculiar properties, and which also causes the difficulties in soldering.

In an article published in this issue Prof. C. F. Burgess and Mr. Carl Hambuechen describe an interesting method of applying to an aluminium surface a coating that sticks. We need not dwell upon the practical importance, as this will be evident to every plater, but we may emphasize that success in this case, as in others, was due to the judicious application of exact principles. Since the oxide film is the cause of all the trouble, it must be removed and an electrolyte must be used which does not allow the film to form again or which will even destroy any traces left. Then the first coating must be made with a metal which alloys well with aluminium; this is zinc. All further plating operations are then the same as plating upon zinc.

WHAT AILED THE DYNAMO?

The story of the sparking dynamo, told in this issue by Mr. David H. Browne, is highly amusing and teaches some instructive lessons. The main moral is that an electrochemical plant should be considered as a complete unit, like an organic body; if one portion of an organic body is out of order, it will affect the whole system, and if there are indications that something is out of order, it is necessary to look for the causes. It is not always the specialist who is the best physician. It is quite inherent in human nature, and in line with our specialization in engineering, that one man is more interested in the chemical part, and another man more in the power-generating part of a plant. This will, of course, always

be so; but if something goes wrong in one part of a plant, the ultimate reason may be found in some other part. In the present case the sparking at the commutator of the dynamo was due to a weak field, and the latter was due to the fact that a number of baths in the electrochemical plant had been disconnected so that the line voltage was lower than that for which the dynamo had been designed.

Mr. Browne is fully justified in emphasizing that there is no use in doctoring symptoms. The repeated turning off of the commutator in the present case had no effect whatever, simply because the commutator itself was not at fault, the sparks being only the symptoms, indicating the fact that the dynamo was operated under conditions for which it was not designed. The lesson taught is that if something is out of order, one should consider the entire plant as a whole, and look for the fundamental cause of the defect. This may be found at quite another place than where the first indications appeared that something was out of order. This may sound commonplace, but is, nevertheless, often overlooked in practice. For instance, in the simplest case of electrolytic action in which a soluble anode is used of the same metal which is to be deposited upon the cathode, it may be found that the cathodic deposition does not proceed properly. To find out the reason, one should consider the whole cell, and should not overlook, for instance, the anode, since the cause of the imperfect cathodic deposition is sometimes due to the fact that the electrolyte is impoverished in the metal ions to be deposited for the reason that the anode has not corroded properly. Doctoring at the cathode would not help matters in this case, since it would be necessary to take care of the anode. It has happened often enough in other cases that the reason of faulty deposition was in the failure of the power supply. For instance, the line voltage may have diminished below the value required for the electrolytic action. By engineers who have been interested in the introduction of the electric precipitation method in the cyanide process in South Africa, it is stated that when the extraction of gold by electrolysis happened to be low, nearly always the unreliability of electric precipitation was cited as the cause, and there the matter very often ended, although it might have been, and sometimes was traced to causes very far removed from its assumed origin, being repeatedly found to be due to a failure of the power supply.

Mr. Browne, who, on account of his nickel-copper process, stands in the front rank of electrometallurgists of the world, has formerly pronounced very concisely and cleverly the fundamental keynote of the successful working of an electrolytic process by emphasizing that initially good conditions should be maintained good during operation. Let us apply this requirement, to the whole plant. It was designed for a certain number of tanks, and provided with a dynamo designed to furnish current for that number. The first requirements of successful working—the initially good conditions—were thus provided, but at the start of operation the number of tanks was changed; this reacted upon the dynamo. It is, of course, very easy to point out such general morals of a story—much easier than it was for the four dynamo and engine experts to find the cause. Mr. Browne's switch, by which the proper exciting current for the field of the dynamo is provided under different conditions of operation, is instructive in showing how it is nearly always possible to rectify matters after one has clearly recognized where the fundamental weak point lies.

ESTIMATING THE OXYGEN CONTENT IN COPPER.

In this issue we publish a fully illustrated account of an extended investigation by Messrs. H. O. Hofman, C. F. Green and R. B. Yerxa, on the microstructure of alloys of copper and cuprous oxide. While the subject is not directly of an electrochemical nature, yet we have no doubt that this paper will be read with much interest by our copper refiners, and, in fact, by every copper metallurgist. It becomes daily more evident that metallographical principles and methods are not only of great scientific interest, but may be made use of to good advantage by the practical metallurgist. The results obtained by Messrs. Hofman, Green and Yerxa are suggestive in this respect. They show that area-measurements of enlarged micrographs of pure coppers containing less oxygen than the eutectic give good valuations of the oxygen-content. Moreover, it seems entirely feasible to make quickly a close estimation of the percentage of cuprous oxide contained in a sample of copper by simply examining a polished surface with the microscope, when once some experience has been gained.

THE CONSTITUTION OF SALT SOLUTIONS.

The Synopsis of this issue contains an abstract of an interesting and suggestive paper of Prof. Abegg, on one of the most fundamental points of the electrolytic dissociation theory. This fundamental point is the determination of the chemical nature of the ions in the case of a given solution. This has always been to some extent a weak point of the theory, in so far as no exact method was known by which one could determine in any case what the ions are, without making more or less arbitrary assumptions. What is best known of the ions, is their properties—their electric charge and their mobility in infinitely dilute solutions. When we adopt the scheme of traveling ions for describing and illustrating the electric phenomena in a solution, we *must* attribute to each monovalent gramion a charge of 96,540 coulombs, and to any ion in an infinitely dilute solution a distinct mobility, dependent only on its own chemical nature. In attributing these two properties to the ions, we do not make any arbitrary assumption, but simply express, in the language of the scheme of ions, the facts given in Faraday's law and ascertained by Kohlrausch in his conductivity measurements with dilute solutions.

It is quite different with the other question; when we have a solution of a given compound in a given solvent, what is the anion and what is the cation? If we only want to know how much of a given substance is deposited or dissolved, etc. by a number of ampere hours in a given cell, the question what the ions are is of no great account, since various assumptions may lead to the same result. This is the reason why, in the past, for a long while many people found it convenient to assume that in an aqueous solution the hydrogen and the

oxygen of the water are the ions; for instance, the reaction of the lead accumulator was often described as though during discharge the lead peroxide was reduced by nascent hydrogen to oxide and the spongy lead was oxidized by nascent oxygen to oxide, the oxide then being secondarily changed into sulphate at both ends; as long as we only want to know how many grams of any substance are changed by a given number of ampere hours, this view gives correct numerical results. Nevertheless, there is an extended series of facts, which have been ascertained, beginning with and since Faraday, and which speak against such an assumption. In fact, in the evolution of the ionic idea we have gradually been led to the exactly opposite assumption that the water practically forms no ions, and that it is the dissolved substance which is ionized.

In the development of this idea, it was then possible to a certain extent to determine experimentally something concerning the chemical nature of the ions. For instance, by his transference number measurements, Hittorf could show that in certain double salts the one metal must be assumed to be contained in a complex anion. Further, if we consider simple salts, for instance all chlorides, in very dilute solutions, then Kohlrausch's measurements show that the anion in infinitely dilute solutions of all chlorides has exactly the same mobility. We therefore conclude that the anion in all dilute chloride solutions is of the same chemical nature, and—on the basis of the hypothesis that it is the dissolved salt which is ionized—we conclude that the anion of any chloride is the chlorine ion, *i. e.*, a negatively charged chlorine atom (or, if we prefer to say so, a compound of a chlorine atom and a negative electron). For more concentrated solutions we assume with Arrhenius that the anion remains of the same chemical nature, and that only the number of the ions (or the number of the ionized molecules of the dissolved substance) changes. What we wish to point out here is that the above fundamental conclusion concerning the chemical nature of the anion in a chloride solution is to some extent arbitrary, *i. e.*, it goes beyond what has actually been determined by experiment. True, in infinitely dilute solutions, we have no right to assume that the anion is chemically a compound of chlorine with molecules of the dissolved substance, since the mobility of the anion is the same for the different chlorides. But so far as the facts have been ascertained, nothing would prevent us from assuming that the anion is some compound of chlorine with water, which is the common solvent. This would lead to a combination of the ideas of the dissociation and association theories, which is in itself not foolish, and which, for more concentrated solutions, at least, has certain facts in its favor.

The leading principle, on which, in the past, all assumptions concerning the chemical nature of the ions were based, was to make the theory as simple as possible; in the case of chlorides the simplest assumption is that chlorine is the anion. This is not said in any derogatory spirit. In the evolution of any theory it is natural to proceed in such a way that one first makes the simplest assumptions and modifies them later, when necessity arises. This has naturally been the case with the dissociation theory, and is well illustrated by the paper of Prof. Abegg. While in full agreement with the assumption that it is the dissolved salt which is ionized, he shows that not all the ions can be of such a simple nature as is generally assumed, and that complex ions must be assumed to exist even in ordinary simple solutions to a far greater extent than might have been expected. Hittorf had already shown that in a solution of $CdCl_2$, there are not only the simple ions $Cd^{\cdot\cdot}$ and Cl', but a considerable number of complex anions of the general formula $(CdCl_2)n\ (Cl')m$. Arrhenius was later led to similar conclusions in other cases in which comparisons of freezing point with conductivity measurements did not agree with his fundamental hypothesis. Abegg and Bodlaender had found that the formation of complex ions is a characteristic feature of double salts; and since the constituents of a complex ion—the simple ions and the not-ionized molecules—exist in the solutions of simple salts, Abegg concluded that complex ions must also exist in the solutions of simple salts. This conclusion was confirmed by his experiments.

The principle of Abegg's investigation is as follows. From conductivity measurements we can find the total number of simple and complex ions. If we now have a method of determining by another method the number of the simple ions alone, we will find to what extent complex ions exist in the solution. The method of determining the number of simple ions of a metal in a solution of a salt of this metal is to measure the potential of an electrode of this metal in the solution (against a normal electrode); by means of Nernst's theory of the e. m. f. of a reversible electrode, the concentration of the simple metal ions in the solution may then be determined. The results of Abegg's investigation are of great interest; they are to the effect that complex ions must be assumed to exist to a large extent in acetates, sulphates and chlorides, and to a smaller extent in nitrates; the metals, the salts of which were examined, being zinc, cadmium, iron, cobalt, nickel, lead and copper. The results are in agreement with what Abegg had expected from his and Bodlaender's theory of electroaffinity.

On the other hand, it is undeniable that to obtain a full proof of Abegg's views, it would be necessary that the numbers of the complex ions are determined by another, different method, and shown to agree with the values found in the first method. As long as this is not done, the only absolutely certain conclusion to be drawn from Prof. Abegg's investigation is that the ordinary assumption (that, for instance, an aqueous solution of zinc sulphate contains only water, zinc sulphate molecules, zinc ions and SO_4 ions) leads to conclusions which are not in agreement with the facts. This is, however, something we already know from the extended researches of Kahlenberg, although Kahlenberg draws a quite different conclusion from the existing disagreement than Abegg does. Abegg assumes the existence of complex ions, being essentially a compound of simple ions with neutral salt molecules. Kahlenberg emphasizes the importance of the chemical affinity between solvent and solute. It is evident that before a decision can be reached, much more experimental facts are to be ascertained.

INTERNATIONAL ELECTRICAL CONGRESS.

As was noticed in our last issue, everything points to a very great success of the International Electrical Congress, which will be held at St. Louis from September 12 to 17, 1904. The number of persons who already have applied for membership is more than sufficient to make a success certain, while more applications for membership are daily coming in, especially from abroad. Collection of fees has commenced, and upon receipt the member is forwarded a certificate of membership, a reproduction of which is shown herewith, since, by a mistake, it was omitted in our last issue. The certificate is 8½ inches by 11 inches in size, and printed on heavy paper. All communications should be addressed to the general secretary, Dr. A. E. Kennelly, Harvard University, Cambridge, Mass.

FARADAY SOCIETY.

A meeting of the (British) Faraday Society was held on February 2, in London, the president, Dr J. W. Swan, being in the chair.

Mr. Jonas read an abstract of a paper by Mr. S. Cowper-Coles, entitled "Notes on the Welding of Aluminium." Soldered aluminium joints have proved unsatisfactory, as they will not stand the test of time. One of the chief difficulties encountered other than the formation of oxide in soldering aluminium is, that a few degrees below its welding point it passes into a pasty or brittle state, and being a very good conductor of heat, the solder very rapidly cools and freezes before it has time to flow sufficiently. He described various machines and processes for welding aluminium, and then went on to describe his own process, which was already noticed on page 31 of our January issue.

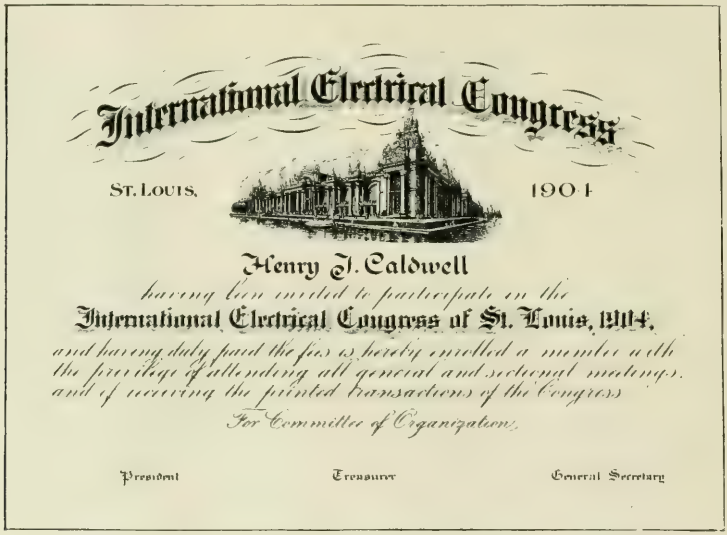
In the discussion which followed, Mr. D. A. Sutherland said that the principle of the method was familiar to metallurgists who had to report on these matters; the great difficulty was where large pieces of aluminium had to be welded. Mr. M. Morrison agreed with the last speaker; he, himself, had welded many joints in this way, although he did not quench. He always found that pressure was necessary; the chief novelty of the Cowper-Coles process lay in the apparatus. Mr. B. Blount said when drawn wires were welded it was essential that the joint be drawn or worked in some way, otherwise, being cast metal, it would be weaker than the rest of the wire. Prof. Huntington thought that the chief novelty in the process lay in the fact that the metal was actually fused. Mr. E. K. Scott said that the important point to remember was the value of the hard outer skin of the metal. If aluminium wires were used for transmission of electricity, uniformity of section was unimportant, and the blob at the weld need not be removed. But otherwise, *e. g.*, if used as trolley wires, it would be necessary to harden the joint in some way; this might be done by burnishing with agate. He showed by a diagram how a connection might be made without welding. Mr. Jonas, in reply to Mr. Blount, said that the joints proved to be the strongest part of the rods. He would remark that the quenching was an essential feature of the process, and one which distinguished it from all others, the process being primarily a fusion process.

Dr. F. M. Perkin then read an abstract of a paper by M. Hollard, entitled "Some Applications of the Theory of Electrolysis to the Separation of Metals from One Another." An abstract of this paper is given in the Synopsis of this issue.

Mr. G. Watson Gray read a short preliminary note describing an explosion of some high-grade ferro-silicon that occurred spontaneously a short time ago at Liverpool. The gases evolved on boiling a specimen in distilled water were found to contain PH_3 and AsH_3. The former was in the greater proportion, and to that probably the explosions were due.

Mr. D. A. Sutherland thought that the presence of only 0.1 per cent phosphorus made it very difficult to account for the explosions being due to phosphoretted hydrogen. It was essential to know the previous history of the metal. Mr. R. H. Harland and Mr. E. K. Scott, who had gone into the matter, believed the explosion was due to calcium carbide, which had been previously made in the same furnace.

Mr. Gray, in his reply, said there was certainly less than 0.1 per cent of calcium in this particular specimen of ferro-silicon. There was no doubt as to the presence of phosphoretted hydrogen in the gases evolved. He would report further in the matter, and Mr. Harland promised to do the same.


International Electrical Congress
St. Louis.
1904
Henry J. Caldwell
having been invited to participate in the
International Electrical Congress of St. Louis, 1904,
and having duly paid the fees is hereby entitled a member with
the privilege of attending all general and sectional meetings,
and of receiving the printed transactions of the Congress
For Committee of Organization
President
Treasurer
General Secretary

CERTIFICATE OF MEMBERSHIP, INTERNATIONAL ELECTRICAL CONGRESS.

ELECTROPLATING UPON ALUMINIUM.

By Charles F. Burgess and Carl Hambuechen.

A review of the many contributions to electrochemical literature concerning the subject of electroplating upon aluminium might lead to the belief that if electroplaters would but follow the directions given therein for obtaining durable, adherent coatings of gold, copper, nickel and various other metals upon aluminium they would encounter no difficulty. Most of the articles dealing with the question refer to it as a hitherto unsolved problem, explain why it is difficult to plate upon aluminium, and then give instructions for operating so that such difficulties may be overcome. Unfortunately, the records stop at this point, and fail to recite the experiences and the results attained in the various attempts that are made to follow such directions.

Adhering to the general formula for contributions on this subject, the authors may state that their attempts to follow many of the published instructions have failed to produce satisfactory results, and that they were thus led to undertake experimental investigation, with results of such a degree of success that they feel warranted in adding further to the literature on hand.

The principal difficulty encountered in the deposition of a metal coating upon aluminium is as regards its adherence. The mistake is commonly made of assuming that a test of this property is complete when the article taken from the plating-tank is subjected to a buffing or polishing operation. The coating must, however, stand the test of time and the chemical and mechanical wear which time and use bring. The adherence may be all that is desired for the first few days or even months, but if the coating is not sufficiently dense and continuous to exclude moisture it may become loose after a certain lapse of time. Deposits which were obtained in the manner described further have now stood the test of over a year's time without an apparent deterioration.

It is generally agreed that the difficulties of plating on aluminium are attributable to the invisible film which forms upon that metal when exposed to the atmosphere or to almost any aqueous solution. Most of the methods recommended for plating require the removal or dissolving of this film by one of the various solvents, such as hydrochloric acid, hydrofluoric acid, or the alkaline hydrates, and the rapid transferrence of the article thus cleaned to the rinsing and then to the plating tank.

The ideal method which naturally suggests itself is, after cleaning the metal by the means suggested, to immerse it in a plating solution of a composition that will act as a solvent for any film that might tend to be formed. In other words, if the plating solution could act as a solvent for the film of aluminium oxide or hydroxide, and at the same time furnish the proper metal ions the elimination of the film difficulty would be ensured.

During the trial of a great many solutions to find one which would combine these properties in a sufficient degree, the best results were obtained by the use of a soluble fluoride in the plating bath. Such fluorides may be present as a sodium, potassium, or ammonium salt, or perhaps preferably as a small quantity of free hydrofluoric acid. Since the fluorine compounds of many of the metals are insoluble, a fluoride cannot be maintained in solution in many of the plating baths. In certain ones, however, notably in zinc sulphate solutions, the precipitate which is first formed on the addition of a small quantity of sodium fluoride or hydrofluoric acid becomes dissolved on standing, and it is from such solutions that adherent deposits may be obtained.

We have noted that certain of the metals have the property of adhering more tenaciously to aluminium than do others, due, possibly, to differences in alloying property, or to the intimacy of contact which can be made between the two metals. Zinc seems to possess the adhering property to a high degree, and consequently the use of this metal is recommended. After once obtaining such adherent deposit of zinc, the article may be transferred to another plating solution from which the finishing coating of the desired metal may be obtained. A disadvantage in the use of zinc as a preliminary coating was found in depositing a layer of gold upon it. While the product seemed at first to be highly satisfactory, the gold disappeared almost completely within a few weeks' time, being absorbed or alloyed by the zinc. This difficulty was overcome by giving the zinc a thin coating of copper from a cyanide solution before applying the gold.

The mode of operation which may be recommended is to first clean the aluminium by immersion for a few minutes in a dilute hydrofluoric acid bath where it remains long enough to produce a suitable roughening of the surface. The deposition upon a rough surface is more adherent than upon a polished one, and this step is therefore of importance. Upon removing the aluminium from this bath it is rinsed in running water and then dipped for a few seconds in a mixture of 100 parts of sulphuric acid and 75 parts of nitric acid, both concentrated, from which, after rinsing in water, the aluminium comes perfectly white and clean. If an impure aluminium or aluminium alloy be treated, it may have a loosely adhering black coating on leaving the hydrofluoric acid dip, and this may be removed satisfactorily by brushing before placing it in the final acid dip.

The aluminium after being thus cleaned is transferred to the zinc plating solution. This consists of a mixture of zinc and aluminium sulphates in the proportion commonly used for zinc plating, very slightly acidified and having a density of about 15 degrees Baume and containing about 1 per cent of hydrofluoric acid or an equivalent amount of potassium fluoride.

While it is desirable that the article be transferred from the cleaning solution into the plating bath without unreasonable delay, it is not essential that it be done with great rapidity, since the plating solution acts also as a cleaning one. After the deposition has proceeded for about ten or fifteen minutes with a current density of from 10 to 20 amperes per square foot, the article may be taken from the solution and dried. It may then be given a coating of copper or silver from their cyanide solutions, using such precautions as are commonly observed in the deposition of such metals upon zinc.

Where the final coating is to be of gold, it may be advantageous to polish the copper coating before depositing the gold, as otherwise a thicker gold coating will be necessary to produce the final polish. It will be seen that by this method of operation the deposition of gold upon aluminium is a somewhat involved process, requiring the preliminary deposition of two different metals upon the aluminium before the final coating of gold is applied, but the exceedingly rapid manipulation required by various other metals is eliminated. The adherence and durability of the final coating depends almost entirely upon the adherence of the aluminium for the zinc. It is to this part of the process that the suggestions herein given specifically refer. Various modifications of the methods of manipulation for the purpose of economy of time and labor may be apparent to the electroplater, and may be employed without departing materially from the principles described.

Applied Electrochemistry Laboratory,
University of Wisconsin.

American Electrochemical Society.—The next general meeting of the American Electrochemical Society, which will be the annual meeting, will be held in Washington, D. C., from April 7 to 9. The second general meeting of this year will probably be held in connection with the International Electrical Congress in St. Louis.

WHAT AILED THE DYNAMO?

By D. H. Browne.

In starting any electrolytic process the troubles which are most perplexing are usually those arising from the dynamo and engine. It is not always possible to start working with exactly the load for which the dynamo is designed. Circumstances necessitate the cutting out of baths which are not working properly. This alters the total line resistance, causes weakening of the magnetic field, and consequent sparking at the commutator, and the man whose entire attention should be given to the proper conduct of the electrolytic operations is suddenly confronted with mechanical and construction problems, often simple enough, but with which he has had little previous experience. To those who have struggled with these difficulties the following notes, collected from the journal of a refining plant, may be of interest.

The dynamo was a new eight-pole, carbon brush, bar commutator machine, built by a large and well-known electrical manufacturing concern, and stated, when purchased, to give at 255 revolutions per minute, 900 amperes at 40 degrees rise of temperature and 1000 amperes with 50 degrees rise. The rated pressure was 120 volts.

This was direct-connected to a new engine 16½ by 16 inches, made by a well-known engine-building firm. The foundations were exceedingly solid, being constructed of one block of concrete. All alignments were most carefully adjusted, and the dynamo tested with a water load before starting the process; so that there was no reason whatever to apprehend any trouble from the dynamo or engine.

On starting the process it was found necessary to cut out some of the baths whereby the line voltage was cut from 120 to 80 volts. This caused sparking at the commutator, which for two months was a continuous source of annoyance, as the journal records show.

January 27, 1901. The dynamo is giving 900 amperes at 90 volts. Sparking under all the brushes. The commutator is again cutting very badly. The engineer was about to turn it off for the third time. Stopped him, as there is no use doctoring symptoms. Wired the electrical company who had built the dynamo to send an expert on the first train.

January 29. Electrical expert arrived; spent all afternoon testing the dynamo and looking for "grounds" in the plating room.

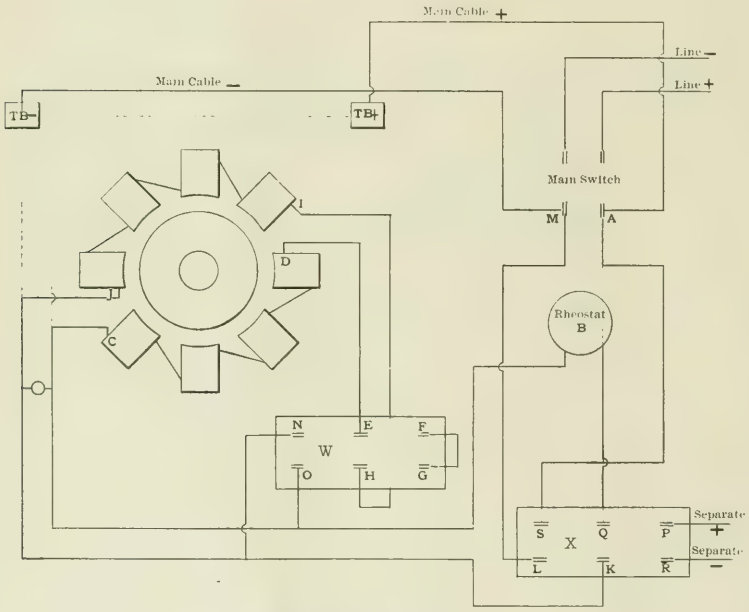
January 30. Expert turned off the commutator and is setting the brushes very exactly. After to-day's dressing down I find commutator has lost 5-16 of an inch diameter in three months.

January 31. Running the dynamo last night and to-day 900 amperes—90 volts. Continuous sparking under all the brushes. Electrical expert says the dynamo is all right, but the engine runs with a jerk. Had the engineer take an indicator card—which certainly looks smooth enough. Telephoned into town for an expert engineer. He came out at noon, and says there is a very slight disturbance in engine, but not enough to cause all this trouble. Both men agree to leave dynamo running over Sunday to see where or why the cutting occurs.

At noon to-day had to stop the dynamo a few minutes. When we started the current was reversed. Noticed that the engineer threw in the resistance coil of the shunt-winding, so as to cut the voltage down before he threw the circuit breaker and pulled the main switch. He should have left the rheostat alone. When the current is on we have line resistance of 90 volts. When the current is off each bath acts like a storage battery, and sends out a reversed current, of about 1.1 volts per bath; giving a total back pressure of 27 volts. With the rheostat cut out the easiest path for this current is back through the field coils—and this, of course, magnetizes the poles in the reverse direction.

To remedy this, disconnect the shunt winding so as to cut the field coils off the main leads. Connect the positive wire from the electric light dynamo to the positive end of the field coils and the negative wire to the opposite side. Lead a current of 10 or 15 amperes through this field winding for two or three minutes. Then slow down the light machine and stop it. Do not break the switch of the light machine while the current is flowing through the field of the big generator or the coils will act like a big induction coil and throw a spark that may burn the insulation. Disconnect the light machine and reconnect the field coils with the main lead.

To prevent this, always keep the voltage on switchboard higher than the back pressure. When the dynamo is to be stopped leave the rheostat alone and throw the circuit breaker with full load on. Then pull the main switch and slow down



CONNECTIONS OF DYNAMO.

Self-Excited Series Field—A B C D E F G H I J K L M.
Self-Excited Multiple Field—A B C D E N K L M and A B O H I J K L M.
Separate-Excited Series Field—P Q B C D E F G H I J K R.
Separate-Excited Multiple Field—P Q B C D E N K R and P Q B O H I J K R.

the engine. This is all very well to know, but it has nothing to do with the commutator trouble.

February 1. The dynamo is still sparking and both experts are still thinking.

February 2. Dynamo is in a bad way. Tried cutting out the shunt and using separate exciting current, but the sparking under each brush is just as bad as ever. Experts went home still thinking. One blames the dynamo, the other condemns the engine.

February 8. The commutator has cut so that the engine room sounds like a thrashing mill. Brushes chatter so that chips of carbon half an inch square fly off. The cutting is on each segment. None are particularly worse than the other, so it cannot be a bad insulation in the commutator.

Electrical expert No. 2 came to-day with a whole bag of tricks to test the insulation.

The trouble simmers down to this: The electrical men say there is a "knock" in the engine. The engine men say the engine is all right, but the trouble is in the generator. Our engineer splits the difference and thinks it is in the flywheel. Telephoned the factory, and they say the fly-wheel was turned to a pound before it left the shop. Took this day a high and holy resolve never again to buy a dynamo from one firm and an engine from another. Get them both from one firm, and then the makers can't indulge in mutual recriminations.

February 9. Engine expert No. 2 out to-day. Took the engine to pieces and ran a fine wire through the centers; find all bearings absolutely true. Got the electrical men to admit this once for all.

February 10. Big job to-day getting engine on its feet again.

February 11. Ran engine to-day to convince the electrical men that it was running smoothly before we started the dynamo with a load. The electrical chief expert wants to turn the commutator off again. Made strenuous objection to doctoring symptoms any more. He says if we turn it off again and the thing still sparks his firm "will take very radical measures." This sounds mysterious, but comforting. Went ahead and turned the commutator. The poor thing begins to look thin.

February 13. Electrical man is digging with a putty knife between the commutator segments. He does not say much. Got load on 80 volts, 900 amperes. Sparked as badly as ever. Expert made some lightning changes from shunt to compound winding and back again, cut current down to 700 amperes. This stopped sparking, but will not do, as we want 900 amperes, not 700.

February 15. 900 amperes on, still sparking. Tried a water load to see what different engine speeds would do.

At 228 revolutions we get 120 volts, 700 amperes, with slight sparking. At 244 revolutions we get 125 volts, 880 amperes, and increased sparking. At 250 revolutions, 125 volts, 1000 amperes, and sparking as badly as ever.

February 16. The electrical man sees a great light; as nearly as I can comprehend his reasoning, it is as follows.

The machine is so designed that when the line pressure is 125 volts, about 15 amperes pass around the field coils. If we have only half the line pressure we get only 7 amperes around the shunt winding, and the field is very weak. We have very much less line resistance than the machine is designed for; hence, the field coils do not receive sufficient current. With this work the amperage should be constant, while the voltage changes with the number of baths in series. We have been keeping the machine at its rated speed while we have been producing a lower voltage, and hence a weaker current in the field coils than the machine is designed for. To tide over a day or so, electrical expert has taken a separate exciting current of about 12 amperes from the electric lighting machine. He has cut the engine to 220 revolutions per minute. We are getting 850 amperes at 70 volts. The current is not quite high enough, but the brushes have ceased sparking, and sweet peace begins to brood over the engine room.

February 17. Electrical expert suggests that when we have less line resistance than the dynamo was designed for we run the engine proportionately slower, and since this cuts down the voltage and the current going round the field coils is proportional to this voltage, we decrease the resistance of the field coils by connecting them in two multiples of 4 poles in series, instead of all eight poles in series. This will cut the resistance of the field coils in two, and so, by doubling the current which flows through them, we will be able to get a strong field with much less line voltage.

February 18. Electrical expert has gone home. He says the engine was all right, and the trouble was all due to weak field. The dynamo is running without spark at 900 amperes, 70 volts. For this relief, much thanks.

We are fitting up two switches. One of these W connects the field coils either in series or multiple. The other X throws either a shunt current or a separate exciting current around the field coils. With self-excited series field the path of the current, as shown in the diagram, will be A, B, C, D, E, F, G, H, I, J, K, L, M.

This current will be used when the generator is running within 25 per cent of its indicated voltage. When the voltage falls to 50 per cent of the indicated amount the multiple field is to be used, but the rheostat must be cut out. The path of current is then A, B, C, D, E, N, K, L, M and A, B, O, H, I, J, K, L, M.

If, however, the dynamo reverses we use separate exciting current, the path of which in series field is as follows: P, Q, B. C. D. E. F. G. H. I. J, K, R.

If a separate exciting current of 5 to 8 amperes is used, the multiple field may be used, the current paths being, P, Q, B, C, D, E, N, K, R, and P, Q, B, O, H, I, J, K, R.

The blocks marked TA and TB are the main cable connections at the base of the dynamo.

These switches were put in operation and the dynamo worked continuously without giving any further trouble.

A LABORATORY STUDY OF THE STAGES IN THE REFINING OF COPPER[1]

By H. O. Hofman, C. F. Green and R. B. Yerxa.

Introduction.

In refining copper, the metal is melted down in a reverberatory furnace in a more or less oxidizing atmosphere and then further subjected to an oxidizing smelting in order to eliminate the common impurities, most of which have a stronger affinity for oxygen than has copper. In these operations some of the copper is oxidized to cuprous oxide and dissolved by the metal bath. When the quantity of dissolved cuprous oxide has reached about 6 per cent, the metal is said to have been brought to "set-copper." A button-sample will show a depressed surface and, when broken, a single bubble at the apex of the depression; the fracture will be brick-red and dull. It is essential to carry the oxidation to this point in order to know that the impurities have been oxidized as far as it is possible under the given working-conditions. Nearly all the cuprous oxide of the set-copper is now reduced to the metallic state by poling, when "tough-pitch" copper will be obtained. A button-sample will show a flat surface. Upon breaking, it will be found that the former bubble has disappeared and that the fracture has become rose-colored and shows a silky lustre. The quantity of cuprous oxide allowed to remain in the copper will vary with the impurities still present in the metal and with the degree of pitch that it is desired to reach. It is essential for the general physical and the mechanical properties of the resulting copper that such impurities as arsenic, antimony, bismuth[2], lead shall be present in the oxidized state, as they are

[1] A paper presented to the American Institute of Mining Engineers.

[2] This generally accepted statement by Hampe (Zeitschrift für Berg-, Hütten- und Salinen-Wesen im Preussischen Staate, 1874, xxii., 121) is doubted by Roberts-Austen (Journal of the Society of Chemical Industry, 1894, xiii., 471), who, in discussing Gowland's paper, "A Japanese Pseudo-Speise (Shiromé)," etc., says, "however small the proportion of bismuth in copper might be, it always remained free, and did not unite with the copper."

then less harmful than when present in the metallic state. Refiners commonly distinguish "ingot- or cake-pitch" and "wire-bar pitch;" copper brought to the former contains more cuprous oxide than the latter. These two pitches are, however, not absolutely fixed; they vary with the practice of the individual refiner and with thickness of the cake or bar that is to be cast: The thicker the piece, the more oxygen will have to remain in the metal, if a flat surface is to be obtained. A third degree of pitch aimed at is that required by very thin castings, such as electrodes 0.5 inch in thickness. As this pitch lies beyond that of wire-bar copper and differs from it more than to permit its being designated merely a shading, it may be called "plate-pitch."

TABLE I.—Results of Heyn's Experiments.

Test No.	Charge. Cu Grams.	Charge. Cu_2O Grams.	Crucible, Lined or Not Lined.	Cu_2O Calculated from O Found by Analysis. (a)	Temperature of Solidification. Beginning.	Temperature of Solidification. Ending.	Observations on the Galvanometer.
				Per Cent.	Degrees Centigrade.	Degrees Centigrade.	
1	450	None.	Not lined.	0.08	1102	.....	Decided retardation at 1102° C.
2	450	"	Lined.	1.16	1095	1085	Long retardation at 1095° C., slow fall to 1083° C., quick rise to 1085° C., long retardation, slow, followed by quick, fall.
3	450	9.0	Lined.	1.75	1089	1084	Slow fall, beginning at 1089° C., retardation at 1086° C., slow fall to 1083° C., sudden rise to 1084° C., long retardation, slow, followed by quick, fall.
4	450	22.5	Lined.	3.4	.....	1084	Fall to 1076° C. without any retardation, sudden rise to 1084° C., long retardation, slow, followed by quick, fall.
5	450	18.0	Lined.	3.5	.....	1084	Fall to 1082° C. without any retardation, sudden rise to 1084° C., long retardation, slow, followed by quick, fall.
6	450	27.0	Lined.	4.7	1116	1084	Slow fall, beginning at 1116° C., very slow fall to 1076° C., sudden rise to 1064° C., long retardation, slow, followed by quick, fall.
7	450	40.5	Lined.	6.3	1149	1084	Slow fall, beginning at 1149° C., very slow fall to 1077° C., sudden rise to 1084° C., long retardation, slow, followed by quick, fall.
8	450	60.0	Lined.	9.0	1186	1084	Slow fall, beginning at 1186° C., slow fall to 1079° C., sudden rise to 1084° C., long retardation, slow, followed by quick, fall.

(a) Reduction by means of hydrogen: "Hampe's Method," Zeitschrift fur Berg-, Hütten und Salinen Wesen im Preussischen Staate, 1873, xxi., 233.

Little was known of the structural relations that existed between copper and cuprous oxide until 1900, when Heyn[3] published the results of his investigations on "copper and oxygen." He took pure copper wire, cut it into small pieces, made up charges of 450 grams each, added to them varying quantities of pure cuprous oxide, melted the mixtures (excepting sample No. 1) in graphite crucibles lined with porcelain, inserted into the fused charges the protected couple of a Le Chatelier thermo-electric pyrometer and made the cooling-curves. Sample No. 1, copper wire alone, was fused in a graphite crucible without a lining in order that the graphite might have a reducing effect upon the small quantity of oxide present, and the resulting fused copper be as free from it as was possible. The results of his experiments are given in Table I., which are represented graphically by the freezing-point curve in the subjoined diagram.

It will be seen from Table I. that upon cooling, only the tests Nos. 1, 4 and 5 show a single fall of temperature, which means that they do not pass through a pasty stage, but freeze suddenly. With the other tests there is a gradual freezing from the beginning to the end of the solidification. With all samples, excepting test No. 1, the cooling is accompanied by surfusion, the depressed temperature rising in every instance to the fixed point of 1084° C. This temperature, corresponding to the freezing-points of tests Nos. 4 and 5 containing 3.4 and 3.5 per cent. Cu_2O respectively, which have only one distinct point of solidification, must be the temperature of the eutectic. The V-shaped freezing-point curve of the diagram, plotted from the data in Table I., and the micrographs, Figs. 1 to 8 inclusive, bring this fact out clearly. Figs. 4 and 5, the eutectic of copper and cuprous oxide with 3.4 and 3.5 per cent. Cu_2O respectively, show the characteristic structure, *i. e.*, a conglomerate of the two components arranged more or less in alternate plates which do not cross one another. With alloys of diminishing percentages of cuprous oxide, shown in Figs. 3, 2 and 1, the micrographs give the dark network of eutectic and the light mesh-work of copper; with alloys having percentages of cuprous oxide greater than 3.4 or 3.5, the micrographs, Figs. 6 and 7, show patches of cuprous oxide increasing in size embedded in eutectic mixture.

The alloys of copper and cuprous oxide, when in the molten state, form homogeneous solutions similar to salt solutions. Upon the solidification of copper-alloys containing less than 3.45 per cent Cu_2O, the cuprous oxide falls out completely and does not form a solid solution with copper. This is seen clearly in Fig. 1, where the network of the eutectic is still visible, when the copper contains only 0.08 per cent Cu_2O. Should any cuprous oxide form a solid solution, its quantity would have to be less than 0.08 per cent. Whether in an alloy with more than 3.45 per cent Cu_2O, the patches of cuprous oxide (Figs. 6 and 7) are pure cuprous oxide, is not settled, but in all probability this is the case.

Finally, Fig. 8 represents the same sample as shown in Fig. 2, *viz.*, copper with 1.16 per cent Cu_2O. In the first case, the specimen has been heated to 1100° C. and then quenched in water of 10° C.; in the second, it has been allowed to cool slowly. The disconnected points in the micrograph of the quenched specimen show how the free development of the inner structure has been arrested; in contrast, Fig. 2 illustrates clearly how the eutectic, if given sufficient time, forms a connected network.

The leading statements of Heyn's paper, including eight of his nine micrographs, have been repeated here, for the reason that they have an important bearing upon the work to be described; in fact, the suggestion in his conclusions that observation of the microstructure of refined copper might be substituted for the lengthy determination of oxygen was the cause of undertaking the present investigation. This embodies the examination of fractures of samples taken in different stages of refining, the determination of the oxygen-content, the preparation of micrographs, and, lastly, the planimetric measurement of enlarged micrographs, with calculation of the percentage of oxygen.

Description of Samples.

Button-samples for this investigation were kindly furnished by Mr. W. T. Burns, of the Boston & Montana Consolidated Copper and Silver Mining Co., Great Falls, Mont., by Mr. M. B. Patch, of the Buffalo Smelting Works, of the Calumet & Hecla Mining Co., Buffalo, N. Y.; and by Mr. G. M. Luther, of the Nichols Chemical Co., Laurel Hill, N. Y.

Sample No. 1 of the Boston & Montana Co. represents cathode copper after it has been melted down in the reverberatory furnace and skimmed, but not rabbled; No. 2 was taken after the rabbling had been completed and the stage of set-copper reached; No. 3 is the sample after the poling has been finished, and the copper is ready to be ladled into wire-bars. The tests made at the works give: silver, 0.8 ounces per ton; arsenic and antimony, 0.0035 per cent; conductivity,

[3] Mittheilungen aus den Königlichen Versuchsanstalten zu Berlin, 1900, xviii., 316; see also The Metallographist, 1903, vi., 49.

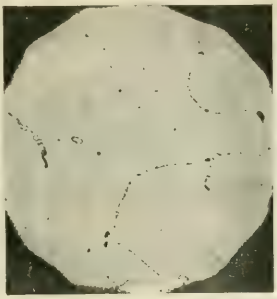


Fig. 1.

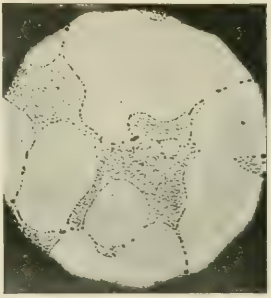


Fig. 2

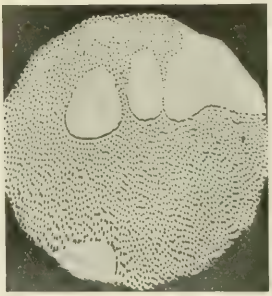


Fig. 3.

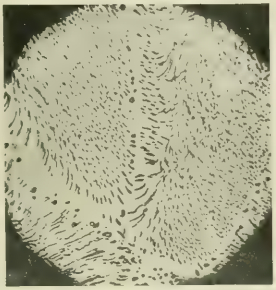


Fig. 4.

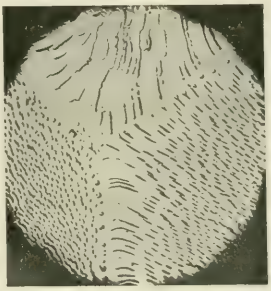


Fig. 5

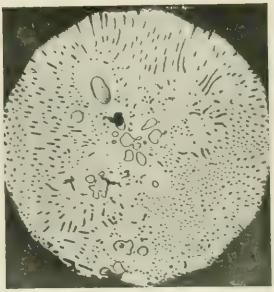


Fig. 6

Fig. 7.

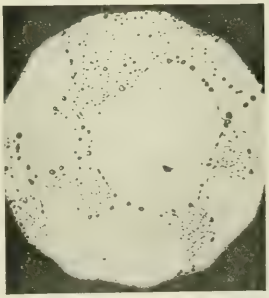


Fig. 8

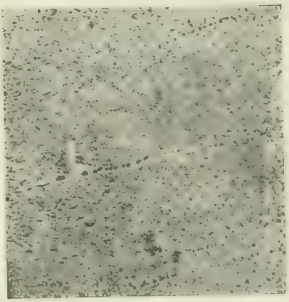


Fig. 19.

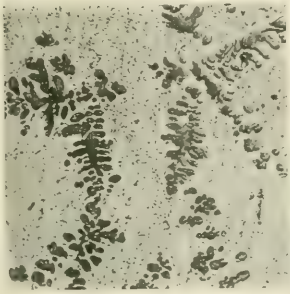


Fig. 20

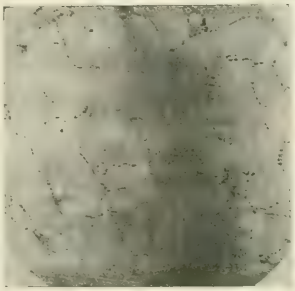


Fig. 21.

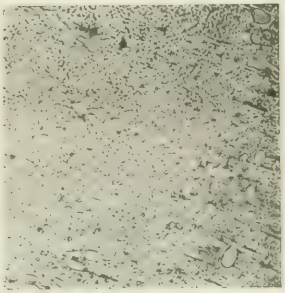


Fig. 22.

Figs. 1 to 8, Copper-Cuprous Oxide Alloys (Heyn), Magnified 123 diameters.
Figs. 19, 20, 21, Samples 1, 2, 3, Boston & Montana copper, containing 3, 6.16 and 0.51 per cent Cu_2O, respectively. Magnified 100 diameters.
Fig. 22.—Sample O, Calumet & Hecla Set Copper, 5.76 per cent. Cu_2O. Magnified 100 diameters.

97.5 per cent; tensile strength, 64,200 pounds per square inch; elongation, 1 per cent; torsion-twists in 6 inches, 89.

Sample No. 0 of the Buffalo Smelting Works represents set-copper; the remaining six of the set, Nos. 1, 2, 3, 4, 5 and 6, were taken at intervals of fifteen minutes during the poling-period: No. 1 was cast after the poles had been in the furnace for fifteen minutes; No. 6 is finished refined copper brought to a pitch at which ingots or cakes are cast. Samples Nos. A and B, from another charge, represent copper brought to ingot-pitch and wire-bar pitch respectively, special care having been taken to allow the samples to cool slowly.

The sample of the Nichols Chemical Co. represents plate-pitch, *i. e.* the pitch desired for casting thin electrodes.

Fractures of Samples.

The fractures reproduced in Figs. 9 to 18, inclusive, were prepared in the usual way. An incision about 0.125 inch in depth was made across the convex side of a button with a cold-chisel, the button then clamped in a vise with the incision just protruding above the jaws, and given one or more shearing blows with a heavy short-handle hammer. With set-copper, one blow was sufficient to break the specimen in two; the nearer the sample approached tough-pitch copper, the larger was the number of blows required to obtain a fracture.

color has changed to a brick-red; in the apex of the depressed surface there has appeared the characteristic single bubble. Finally, Fig. 11 represents refined copper brought to wire-bar pitch; the fracture is finely-granular and fibrous, the lustre is very silky, and the color roseate.

Samples Nos. 0 to 6 of the Calumet & Hecla Co., shown in Figs. 12 to 18, begin with set-copper and end with ingot-copper. The fractures, starting from coarse-columnar and cubical (Fig. 12), lose their columnar character, remaining coarse and cubical (Fig. 13), they become coarsely radiated (Fig. 14), then the radiation assumes finer forms and granulation puts in an appearance (Fig. 15), granulation predominates over radiation (Fig. 16), both become finer (Fig. 17), until with Fig. 18 radiation has been entirely replaced by granulation. In a similar manner the lustre, from being absent with Fig. 12, becomes at first slightly silky; then silkiness increases until full silkiness is reached with Fig. 18. The dark brick-red color of Fig. 12 becomes lighter (Figs. 13, 14 and 15), rose-color begins to be seen (Figs. 15 and 16) until full rose-color is reached with Fig. 18.

The observations on the fractures are brought together in Table II.

Determination of Oxygen in Samples.

The oxygen of the different samples was determined by

TABLE II.—Observations on Fractures of Sample-Buttons.

Properties.	Boston & Montana. Samples.			Calumet & Hecla. Samples.						
	No. 1.	No 2.	No. 3.	No. 0.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No 6.
Texture	Radiated, columnar.	Columnar, cubical, coarse.	Finely-granular, fibrous.	Cubical, columnar, quite coarse.	Cubical, coarse.	Radiated, coarse.	Finely-radiated, somewhat granular.	Granular to finely-radiated.	Finely-granular, with some fine radiation.	Finely-granular.
Lustre	Dull.	Dull.	Very silky.	Dull.	Dull, with specks of silkiness.	Dull, with	increasing	silkiness.	Half dull, half silky.	Nearly full silkiness.
Color	Dark brick.	Brick.	Rose.	Brick.	Brick.	Light brick.	Light brick.	Light brick to rose.	Light brick to rose.	Rose.

Several experiments were made to find the best light and time of exposure necessary, the position of the specimen with regard to the light, and the proper magnification to bring out the details in a photograph. A reversible-back Premo camera, 4 by 5 inches, was used with sunlight, the specimen having been placed on a white background. Exposures of 40, 80 and 160 seconds were tried, using a No. 32 diaphragm. With negatives half the size, the same size, one and one-half times and twice the size of the original, exposures of from 40 to 80 seconds gave good results. Trying back-light and side-light, it was found that the latter brought out the structure more satisfactorily than the former. A magnification of one and one-half was necessary to show clearly the details in the photograph.

As it is not easy to have constant conditions with sunlight, electric light from a sixteen-candle-power incandescent lamp was substituted and an enlarging camera of E. & N. T. Anthony used. With the light placed at about 5 inches from the specimen, so as to make an angle of 45° with the face, and using the middle diaphragm, an exposure of six minutes gave the best negative. With finely-granular fractures, filtering the light through ground glass was an improvement, but the time of exposure had to be prolonged to ten minutes; with the coarser structures, better results were obtained without the ground glass.

Figs. 9, 10 and 11 give the fractures of the Boston & Montana samples Nos. 1, 2 and 3 in one and one-half times their natural sizes. Fig. 9, cathode copper after melting and skimming, but before rabbling, has a fracture radiated and columnar, lustre is absent, the color a dark red. Fig. 10 is set-copper, the fracture has lost its radial character and has become coarse-columnar to coarse-cubical, it remains dull, the

means of Hampe's method,[4] which consists in reducing the oxide of finely-divided copper (brought to a bright red heat) in a current of hydrogen, the loss in weight giving a measure for the oxygen-content. Hampe,[5] and later Heyn,[6] gave evidence that the reduction is complete. The apparatus used and recommended by Hampe was somewhat modified, partly along the lines suggested by Archbutt[7] and partly by changes which suggested themselves during the work. On account of the smallness of the samples, it was necessary to use less material for the analyses than did Hampe, *viz.* from 10 to 13 grams. The apparatus used consisted of a 16.5-inch Kipp gas-generator (charged with hydrochloric acid and feather zinc), a gas-washing bottle filled two-thirds full with a saturated solution of caustic soda, a drying-tower with sticks of caustic soda, a U-tube filled with calcium chloride, a bulb-tube filled with copper borings and a second U-tube filled with calcium chloride.

The bulb-tube, of Bohemian glass, 3-16-inch thick, was 8 inches long, and had a bulb 3 inches long and 1.25 inches in diameter. It was supported by a frame (5 inches long by 3 inches wide, by 2.5 inches high) of "uralite" (an asbestos boarding) having slots 1.25 inches deep in the ends to receive the cylindrical ends of the bulb. The frame was placed on a thin sheet of asbestos-paper[8] resting upon a ring-stand. Under this was placed a Tirrel burner with a flame spreader.

[4] Zeitschrift fur Berg-, Hutten und Salinen Wesen im Preussischen Staate, 1873, xxi., 231.

[5] Op. cit., p. 234.

[6] Zeitschrift des Vereins deutscher Ingenieure, 1900, xliv., 509; see also Metallographist, 1900, vi., 48.

[7] Analyst, 1900, xxv., 253.

[8] Asbestos was chosen after sheet iron (used by Archbutt) had failed with the heating apparatus used, and coper had become oxidized and perforated too quickly.

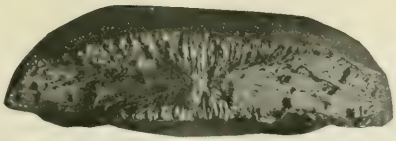


Fig. 9. Sample No. 1, Fracture of Boston & Montana Copper After melting, contains 3 per cent Cu_2O. (?) (Magnified 1.5 diam.)

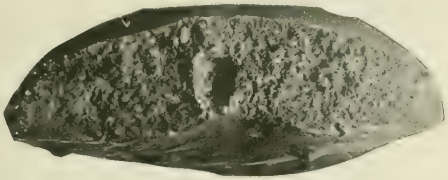


Fig. 10.—Sample No. 2, Fracture of Boston & Montana Copper. Set copper, contains 6.16 per cent Cu_2O. (Magnified 1.5 diam.)

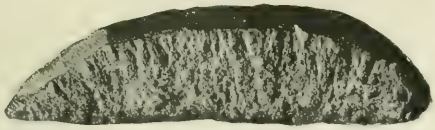


Fig. 11.—Sample No. 3, Fracture of Boston & Montana Copper. Wire-Bar, contains 0.51 per cent Cu_2O. (Magnified 1.5 diam.)

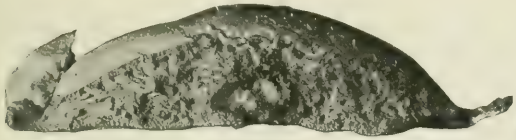


Fig. 12.—Sample No. 0, Fracture of Calumet & Hecla Copper. Set copper, contains 5.76 per cent Cu_2O. (Magnified 1.5 diam.)

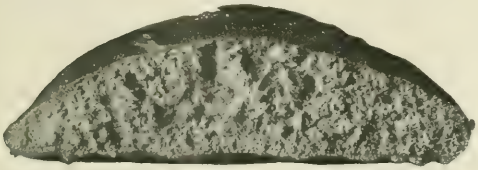


Fig. 13.—Sample No. 1, Fracture of Calumet & Hecla Copper. After poling 15 minutes, contains 5.67 per cent Cu_2O. (Magnified 1.5 diam.)

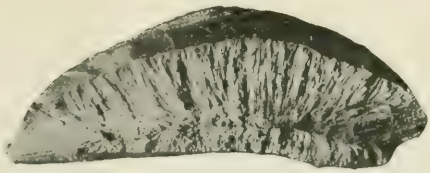


Fig. 14.—Sample No. 2, Fracture of Calumet & Hecla Copper. After poling 30 minutes, contains 3.36 per cent Cu_2O. (Magnified 1.5 diam.)

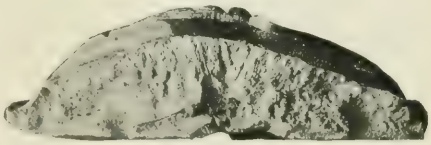


Fig. 15.—Sample No. 3, Fracture of Calumet & Hecla Copper. After poling 45 minutes, contains 1.86 per cent Cu_2O. (Magnified 1.5 diam.)

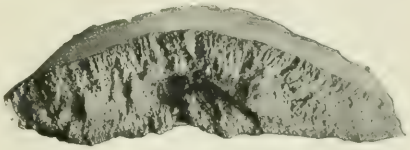


Fig. 16.—Sample No. 4, Fracture of Calumet & Hecla Copper. After poling 60 minutes, contains 1.98 per cent Cu_2O. (Magnified 1.5 diam.)

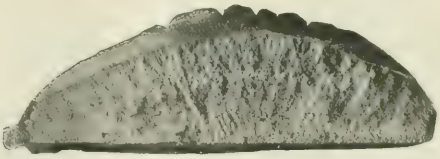


Fig. 17. Sample No. 5, Fracture of Calumet & Hecla Copper. After poling 75 minutes, contains 0.84 per cent Cu_2O. (Magnified 1.5 diam.)

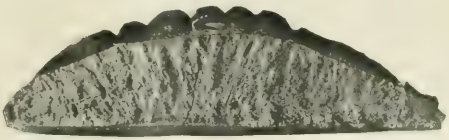


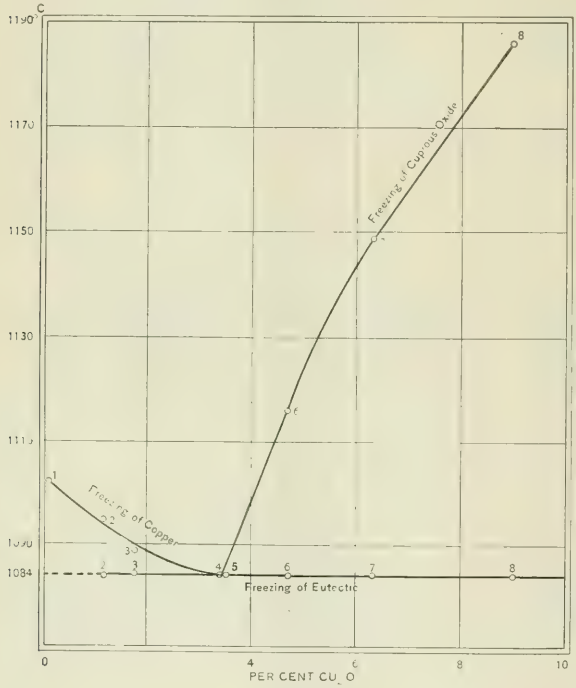
Fig. 18.—Sample No. 6, Fracture of Calumet & Hecla Copper. After poling 90 minutes (Ingot Copper), contains 0.47 per cent Cu_2O. (Magnified 1.5 diam.)

The whole was enclosed by a frame of heavy asbestos matting (7 inches long by 6 inches wide by 13 inches high) with slots in the sides to receive the protruding cylindrical ends of the bulb.

The mode of procedure was as follows: From 20 to 25 grams of borings[9] were taken for a sample, small bits of iron were removed by a magnet, the borings were washed in a beaker four or five times with alcohol and dried to remove the last traces of alcohol, care being taken to avoid any oxidation of the copper. The borings were then divided into approximately equal parts, transferred to the weighed bulb-tubes and weighed. A bulb was placed in the furnace, connected by rubber tubing with the train of hydrogen-apparatus, hydrogen passed through for five minutes at the rate of six bubbles per second, the gas issuing from the second calcium-chloride tube ignited and the bulb slowly brought to a bright-red heat. When water ceased to appear in the glass leading to the second calcium-chloride tube, the gas-current was reduced so that only three bubbles passed the wash-bottle per second, and the bulb kept at a bright-red heat for one and a half hours. At the end of this time, the supply of gas was again increased to six bubbles per second, the lamp removed and the copper allowed to cool. When cool, the bulb was disconnected, air aspirated through it, and the bulb cleaned and weighed.

TABLE III.—Determinations of Oxygen in Samples of Copper.

Sample.		Weight of Copper Used.	Weight of Oxygen Found.	Quantity of Oxygen in Copper.	Quantity of Cuprous Oxide in Copper.
		Grams.	Grams.	Per Cent.	Per Cent.
Boston and Montana.	No. 1	9.9251	0.0319	0.322*	2.88 *
		10.2990	0.0347	0.337*	3.015*
	No. 2	10.1953	0.0702	0.688	6.159
		13.2269	0.0873	0.659	5.905
	No. 3	6.7495	0.0034	0.056	0.503
		6.7671	0.0048	0.058	0.523
Calumet and Hecla...	No. 0	10.5543	0.0679	0.643	5.757
		11.5738	0.0744	0.643	5.755
	No. 1	12.6041	0.0791	0.628	5.618
		10.9886	0.0700	0.640	5.725
	No. 2	11.9961	0.0430	0.358	3.207
		12.1626	0.0456	0.375	3.360
	No. 3	11.8479	0.0242	0.205	1.830
		16.2051	0.3440	0.212	1.900
	No. 4	12.6454	0.2940	0.221	1.980
		13.8294	0.3080	0.223	1.990
	No. 5	13.3018	0.1250	0.094	0.841
		18.2256	0.1690	0.093	0.839
	No. 6	11.3544	0.0059	0.052	0.465
		12.2972	0.0052	0.058	0.524
		13.1625	0.0068	0.052	0.463



FREEZING-POINT CURVE OF COPPER-CUPROUS OXIDE ALLOYS.

The results obtained are given in Table III. It will be noticed that the average percentage of cuprous oxide of the Boston & Montana wire-bar copper is higher than that of the Calumet & Hecla cake-copper, although the former had been brought to a higher pitch and should, therefore, contain less oxygen. The discrepancy may be explained by the fact that the Boston & Montana copper contains more impurities than the Calumet & Hecla; and these impurities are present as oxides.

[9] In boring, the drill was run very slowly to prevent the heating of the sample.

Microscopical Examination of Samples.

The pieces of copper used for making micro-sections were sawed out as nearly as possible from the center of a fracture, as it was thought that some segregation might have taken place in the cooling. Later observations, however, showed that this precaution was unnecessary as long as the superficially oxidized surface was excluded. The samples were all finished with the polishing-machine made by the Boston Testing-Laboratories.[10] In using the machine for rough-polishing, the emery on the canvas-wheel pitted the surface to such an extent that it became necessary to file the specimen smooth before proceeding any further. In regular work, therefore, the sawed specimens were first treated with a rough, followed by a smooth file, and then polished with rouge and water on a revolving wooden disc covered with broadcloth. In polishing, considerable difficulties were encountered at first, as the polished surfaces, when examined under the microscope, showed disturbing scratches. Polishing by hand with rouge and water on a smooth board, covered first with sheet-rubber and then with chamois, gave a more lustrous surface than when the wheel was used, but at the same time it intensified the scratches. This pointed to the probable presence of coarse particles in the rouge. In order to remove them, about one volume of rouge was stirred up with two volumes of water in a beaker, allowed to settle for about 30 seconds, and the suspended matter applied with a brush to the broadcloth disc. The results were satisfactory, and all samples were treated in this manner. When polished, they were cleaned with alcohol and wiped dry with chamois. By thus applying the rouge, running of water onto the machine could be dispensed with, which made the whole operation cleaner. Experiments with decanting the suspended rouge from that which had settled, filtering and then applying the filter-contents to the disc did not work well.

In examining the polished sections with the microscope,[11] magnifications ranging from 30 to 750 diameters were tried. As a high magnification did not bring out the structure more clearly than did one of a smaller diameter, but only narrowed the field of observation, a comparatively low magnification of 100 diameters was chosen. This gave a magnification of about

* These samples contained some sulphur, which was given off as hydrogen sulphide; the figures represent, therefore, oxygen plus sulphur, and not sulphur alone—and the figures in the last column ought to be too high, but, as seen by micrograph, Fig. 19, they are very much too low.

[10] Metallographist, 1901, iv., 275.

[11] Made by C. Reichert, Vienna (Bausch & Lomb Optical Co., Rochester, N. Y.)

230 diameters on the photographic plate. To the eye the contrast between the black[12] cuprous oxide in the eutectic (or the bluish-black excess-cuprous oxide in samples containing over 3.45 per cent Cu_2O) with the red-colored copper was clearly visible, but the photographic plate failed to show it. In order to bring out the structure more clearly, various attempts were made to etch with nitric acid, sulphuric acid, silver nitrate and with the electric current, but they did not improve matters. Heat-tinting did some good, but not enough. Yellow and orange-colored screens were then tried; of these the orange-colored glass proved to be the better, especially when a rapid isochromatic plate particularly sensitive to orange and yellow light was used for photographing. The orange light gave the copper a yellowish tint, but had little effect upon the cuprous oxide. The copper alone having an actinic effect upon the photographic plate, it appeared white in the positive, and the cuprous oxide black. The time of exposure giving the best results was found to be two and a half minutes.

The Boston & Montana sample No. 1 (Fig. 19), taken after melting and skimming the cathodes, is seen to contain a slight excess of cuprous oxide over the eutectic, although the analysis gives only 3 per cent cuprous oxide. The black crystals are small, but easily distinguished from the cuprous oxide of the eutectic. Sample No. 2 (Fig. 20), set-copper, contains a large excess of cuprous oxide over the eutectic; it shows fern-like forms which spring up in relief against the eutectic background. The fern-like forms are very unevenly distributed; the eutectic field in some places was free from them, in others

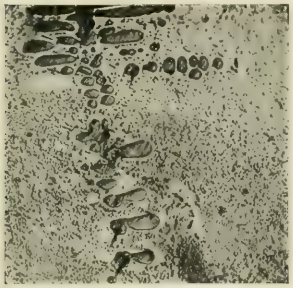


Fig. 23. Sample No. 1, Micrograph of Calumet & Hecla Copper. After Poling 15 Minutes, contains 5.67 per cent Cu_2O (magnified 100 diam.)

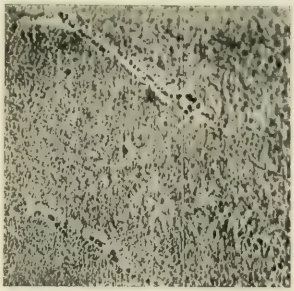


Fig. 24.—Sample No. 2, Micrograph of Calumet & Hecla Copper. After Poling 30 Minutes, contains 3.36 per cent Cu_2O (magnified 100 diam.)

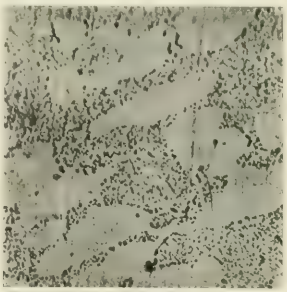


Fig. 25. Sample No. 3, Micrograph of Calumet & Hecla Copper. After Poling 45 Minutes, contains 1.86 per cent Cu_2O (magnified 100 diam.)

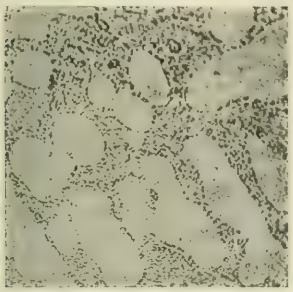


Fig. 26.—Sample No. 4, Micrograph of Calumet & Hecla Copper. After Poling 60 Minutes, contains 1.98 per cent Cu_2O (magnified 100 diam.)

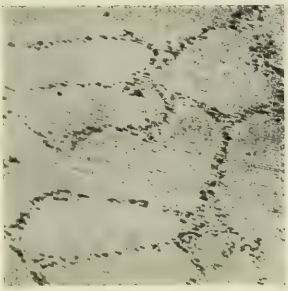


Fig. 27.—Sample No. 5, Micrograph of Calumet & Hecla Copper. After Poling 75 Minutes, contains 0.84 per cent Cu_2O (magnified 100 diam.)

Fig. 28.—Sample No. 6, Micrograph of Calumet & Hecla Copper. After Poling 90 Minutes, contains 0.47 per cent Cu_2O (magnified 100 diam.) (Ingot Copper Cooled Quickly.)

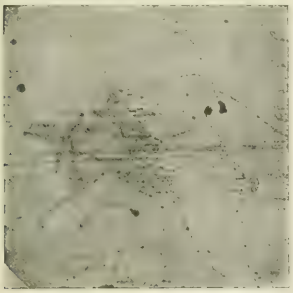


Fig. 29.—Sample "A," Micrograph of Calumet & Hecla Ingot Copper Cooled Slowly, contains 0.91 per cent Cu_2O (magnified 100 diam.)

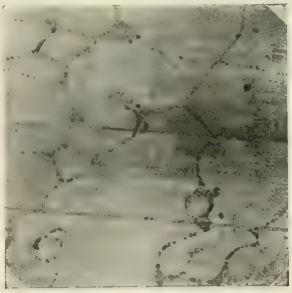


Fig. 30. Sample "B," Micrograph of Calumet & Hecla Wire-Bar Copper Cooled Slowly, contains 0.275 per cent Cu_2O (magnified 100 diam.)

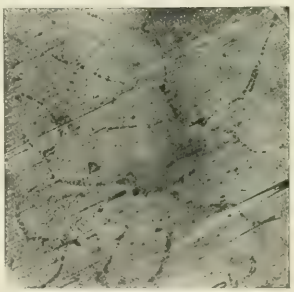


Fig. 31.—Sample of Micrograph of Nichols & Co.'s Plate-Copper (magnified 100 diam.)

[12] To Heyn, op. cit., using chemically pure materials, it appeared bluish-black.

it was entirely covered with them. Sample No. 3 (Fig. 21), wire-bar copper, shows an evenly distributed fine network of eutectic enclosing large meshes of copper.

In the Calumet & Hecla series, sample No. 0 (Fig. 22), set-copper, shows patches of excess-cuprous oxide in the eutectic. Sample No. 1 (Fig. 23), taken fifteen minutes ofter poling had begun, does not differ much from sample No. 0, proving that the reduction had not proceeded very far. On the whole, both samples resemble very much the set-copper sample (No. 2) of the Boston & Montana, although they do not show the fern-like forms so clearly developed. The eutectic, in most cases, is slightly separated from the patches of excess-cuprous oxide crystals by a narrow band of copper, and the cuprous oxide in the eutectic seems to have separated somewhat from its copper, thus giving the field a spherulitic appearance.[13] In sample No. 2 (Fig. 24), the third taken, reduction has progressed rapidly, but it still contains a slight excess of cuprous oxide over that of the eutectic mixture. It resembles sample No. 1 of the Boston & Montana series. In sample No. 3 (Fig. 25), the eutectic has been passed, and the excess-copper becomes apparent. Sample No. 4 (Fig. 26) shows that little progress was made in the reduction in the fifteen minutes that elapsed between the taking of samples No. 3 and No. 4. An explanation for this is that during this period, forty-five minutes after poling had begun, the poles were withdrawn and new ones put in their places. In sample No. 5 (Fig. 27), the cuprous oxide is very much diminished, the eutectic forms a thin network enclosing copper in its meshes. Finally, sample No. 6 (Fig. 28) represents refined copper brought to ingot-pitch. The network of the eutectic is imperfect and broken, and the dark parts of the eutectic are bunched together and larger than expected. The explanation of this peculiar structure may be found, when Figs. 2 and 8 of Heyn's micrographs are compared, by the supposition that the sample was chilled when still above 1084° C., the melting point of the eutectic, which prevented the eutectic from separating out in the form of a continuous skeleton. In order to find out whether this idea was a correct one, a new sample (A), taken at the ingot-copper stage from another furnace-charge and cooled slowly was obtained and examined. Fig. 29 brings out clearly the difference between quick and slow cooling. Fig. 30, sample (B), represents the same batch of copper when ready to be ladled into wire-bar, the sample having been also cooled slowly. The skeleton here also is seen to be continuous and not broken, as in Fig. 28.

Finally, micrograph Fig. 31 represents a sample of copper from the Nichols Chemical Co. which has been brought to plate-pitch, *i. e.*, the poling has been carried further than is the case with the highest degree of wire-bar pitch of the Calumet & Hecla Co.

Area-Measurements.

Measurements of areas which gave Sauveur[14] such interesting facts seemed very promising when applied to samples of copper containing less cuprous oxide than the eutectic mixture. Measuring the copper-areas and deducting them from the total area would give the eutectic area, and from this the percentage of cuprous oxide could be readily calculated. It would be useless, if not impossible, to measure the areas of cuprous oxide in the eutectic; and on account of the unequal distribution of cuprous oxide in specimens with more cuprous oxide than the eutectic, the data would be misleading.

For the purpose of measurement, enlargements were made of sample No. 3 (wire-bar copper) from the Boston & Montana Co., of samples Nos. 3, 4, 5 and 6 (ingot-copper, chilled) from the Calumet & Hecla Co.; also of sample A (ingot-copper, cooled slowly) and sample B (wire-bar copper, cooled slowly) from the Calumet & Hecla Co.; and of the sample of plate-copper from the Nichols Chemical Co.

[13] See H. M. Howe, "Iron, Steel and Other Alloys," Boston, 1903, p. 41.

[14] Trans., XXII, 578.

The enlargements measured 16 by 20 inches, giving five times the magnification of the micrographs, or about 1150 diameters. A circle, 12 inches in diameter, was drawn on an enlargement, divided into four quadrants, and measurements made on each. The Amsler planimeter was the instrument employed. It is commonly used for the measurement of indicator-cards, and is accurate to 0.1 per cent. The copper areas on an enlarged micrograph were outlined with a pencil in order to facilitate measurement. All measurements were carried out in duplicate. It took from 1.5 to 2 hours to measure the copper-areas of a micrograph, the time varying with the clearness with which the edges of the eutectic were defined. Thus, samples No. 5 and especially No. 6 of the Calumet & Hecla series were very difficult to measure. In calculating the percentage of cuprous oxide in the eutectic, the figure 3.45 was chosen, being the average of Heyn's two determinations, 3.4 and 3.5.

The degree of accuracy of the measurements, carried out at least in duplicate, is shown by examples in Table IV., in which A-V represent the copper-areas of one sample.

TABLE IV.—Planimeter Measurements of Copper-Areas.

Copper-Area.	A.	B.	C.	D.	E.	F.	G.	H.
Square inches	2.35	1.04	1.61	2.24	0.27	10.17	2.56	8.26
	2.33	1.04	1.61	2.24	0.27	10.13	2.56	8.27
	2.35	....	....	....	....	10.14	....	....

Copper-Area.	I.	J.	K.	L.	M.	N.	O.	P.
Square inches	0.78	2.83	7.90	4.57	3.20	5.22	3.39	3.14
	0.78	2.83	7.87	4.57	3.20	5.20	3.42	3.12
	....	....	7.86	....	....	5.20	3.40	3.12

Copper-Area.	Q.	R.	S.	T.	U.	V.	....	....
Square inches	5.47	6.57	4.04	2.21	2.91	2.80	....	...
	5.45	6.53	4.01	2.21	2.87	2.80	....	.. .
	....	6.57	4.00	....	2.84	....	....	....
	....	....	....	....	2.84	....	....	....

The percentages of cuprous oxide resulting from the measurements in the several quadrants and the averages are given in Table V.

TABLE V.—Planimeter Measurements of Quadrants of Various Samples.

Sample.	First Quadrant.	Second Quadrant.	Third Quadrant.	Fourth Quadrant.	Average of Quadrants.
No. 3 (B. & M.)	0.58	0.52	0.36	0.48	0.49
No. 3 (C. & H.)	2.34	1.76	1.32	1.84	1.79
No. 4 (C. & H.)	2.00	1.37	1.95	2.06	1.85
No. 5 (C. & H.)	1.00	1.15	0.31	1.11	0.89
No. 6 (C. & H.)	0.39	0.93	0.61	0.30	0.56

It will be seen that the measurements of the quadrants of a sample show some discrepanices, as the copper-islands are not uniformly distributed in the eutectic network. An excess of constituent in one quadrant is, however, balanced by a lack in another, giving on the whole a very satisfactory average.

The results obtained by fracturing and by chemical and microscopical analysis are brought together in Table VI.

The features relating to fractures have already been summarized. Comparing the cuprous-oxide content obtained by chemical analysis and by planimetric measurement, it will be seen that the percentage of cuprous oxide found by analysis in the Boston & Montana sample No. 3, and in the Calumet & Hecla samples Nos. 3 and 4, is somewhat higher than that by measurement. This may be due to the fact that the chemical analysis gives the total oxygen, that of the copper, as well as that of the impurities, while measurement gives only the oxygen of the copper. That the oxygen found by analysis in the Calumet & Hecla samples Nos. 5 and 6 is lower than that obtained by measurement is probably due to the segregation of the cuprous oxide in the eutectic, causing the latter to spread somewhat. Taking the results as a whole, they show that area-

TABLE VI.—PHYSICAL CHARACTERISTICS AND CORRESPONDING CONTENT OF CUPROUS OXIDE AND OXYGEN IN VARIOUS SAMPLES

Mark of Sample.	Boston & Montana.			Calumet & Hecla.							Nichols Chemical Co.		
	No. 1.	No. 2.	No. 3.	No. 0.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	A.	B.	
Fracture	Radiated, columnar.	Columnar, cubical, coarse.	Finely-granular, fibrous.	Columnar, cubical, coarse.	Cubical, coarse.	Radiated, coarse.	Finely-radiated, somewhat granular.	Granulated to finely-radiated.	Finely-granular, finely-radiated.	Finely-granular, finely-radiated.	Finely-granular, finely-radiated.	Finely-granular, fibrous.	Finely-granular.
Lustre	Dull.	Dull.	Very silky.	Dull.	Dull, specks of silkiness.	Dull, more silkiness.	Dull, more silkiness.	Less dull, more silkiness.	Half dull, half silky.	Nearly full silkiness.	Nearly full silkiness.	Full silkiness.	Less silky than A.
Color	Dark brick.	Brick.	Rose.	Brick.	Brick.	Light brick.	Light brick.	Light brick to rose.	Light brick to rose.	Rose.	Rose.	Rose.	Rose.
Per cent. of cuprous oxide, by analysis	3.00	6.16	0.51	5.76	5.67	3.36	1.86	1.98	0.84	0.47	.....	.....	.....
Per cent. of cuprous oxide, by measurement	.....	.....	0.49	.....	.....	.....	1.79	1.85	0.89	0.56	0.91	0.39	0.28
Per cent. of oxygen, by analysis	0.33	0.69	0.057	0.64	0.63	0.38	0.21	0.22	0.094	0.053	.....	.....	.....
Per cent. of oxygen, by measurement	.....	.....	0.055	.....	.....	.....	0.20	0.21	0.099	0.063	0.102	0.043	0.031

measurements of enlarged micrographs of pure coppers containing less oxygen than the eutectic give good valuations of the oxygen-content. Further, it seems entirely feasible to make quickly a close estimation of the percentage of cuprous oxide contained in a sample of copper by simply examining a polished surface with the microscope, when once some experience has been gained. The mode of operating might be as follows: To take a button-sample, cool it slowly and quench it when it had solidified, cut out a piece with a circular saw, grind it smooth on a number of revolving wooden discs covered with emery-cloth or on revolving files, polish with rouge and water on a revolving disc covered with broadcloth (a mirror-like surface would not be necessary), and estimate with the microscope the percentage of cuprous oxide present. The whole operation could be done in from six to eight minutes. The poling could then be controlled by the microscope, and the degree of pitch desired for ingot-, large or small cake-, wire-bar- or electrode copper defined by a readily ascertainable amount of cuprous oxide that should be present.

In conclusion we wish to thank Professors Richards and Fay for many valuable suggestions made during the course of the investigation.

ANOTHER NEW METAL.—From a recent consular report, we quote as follows: "A new metal, which is similar to aluminium, but still of lesser weight, has been discovered by the French engineer, Albert Nodon, and called 'nodium,' after him. It is manufactured by an electric process. In color, lustre, and structure it is almost exactly like steel. Its specific weight when molten is only 2.4. Its resistance against breaking is given as about 20 pounds per square of 0.04 inch. Its constancy in the air is higher than that of aluminium. Its ductility is between 6 to 8 inches; the malleability can be compared to that of bronze. It melts at about 600°. It is suitable for being cast into forms. The conductibility for the electric current is as high as that of copper of equal weight. If natural power, especially water power, can be used for its manufacture, the cost in round figures is about 15 cents per pound. The inventor expects numerous uses of nodium in the near future, especially for electric wires and cables, for light but strong parts of motor cars, torpedo-boats, men-of-war, street cars, military outfits, air ships, etc., and for castings in place of bronze, German silver, and similar metals. Nothing definite has yet been communicated as to the chemical composition of nodium nor as to the mode of its manufacture." It would be interesting to get some more authentical information on the properties and composition of this metal.

PHILADELPHIA SECTION OF THE AMERICAN ELECTROCHEMICAL SOCIETY.

The first meeting of this section was held in the lecture hall of the Engineers' Club, of Philadelphia, on February 5, Mr. Carl Hering being in the chair, and Mr. S. S. Sadtler acting as secretary. The attendance was comparatively small, but the discussions were quite animated, and of a high order, although they turned occasionally far away from the exact subject under consideration. The meeting, being decidedly informal, was a full success.

COMPOSITE VOLTAGE.

The first paper was presented by Prof. J. W. RICHARDS, on this subject. When a current passes through an electrolyte, a part of the energy consumed appears in the form of Joulean heat, while the balance corresponds to the energy of the electrochemical action. It is with this latter energy that the author deals. He purposely neglects any thermoelectric effect and bases his considerations simply upon Thomson's rule.

As long as there is one single electrochemical action, the energy corresponding to it is easily found from thermochemical data. If we know how many coulombs have passed through the cell (which are directly found from the quantities of substances reduced and oxidized at the two electrodes, with the aid of Faraday's law), we may divide the total energy consumed (in watt seconds or volt coulombs) by the total amount of coulombs, and then get the e. m. f. in volts which corresponds to this single electrochemical action. For instance, in copper plating with the use of a soluble copper anode, as long as we neglect the Joulean heat, and as long as the solution is throughout of uniform concentration, there is theoretically no energy required to dissolve copper at the anode, and deposit it on the cathode, hence the e. m. f. corresponding to this electrochemical action is also zero. If acidulated water is electrolyzed between platinum electrodes with a resulting evolution of hydrogen at the cathode, and oxygen at the anode, the energy of the electrochemical action is equal and opposite to the heat of the formation of water from hydrogen and oxygen. If we calculate this energy in watt seconds for that amount of water which is decomposed by one coulomb, we get the e. m. f. of the electrochemical action in volts. All this is well known.

What Dr. Richards discusses in his paper is the case that not a single electrochemical action is going on, but several different actions simultaneously. How is the voltage of the electrochemical action to be calculated in this case. For instance, in one step of the Browne process, both copper and nickel are dissolved from the copper-nickel anodes, while copper only is deposited upon the cathodes. Here we have two distinct electrochemical actions, the one being the same as in

copper plating, in so far as copper goes into the solution at the anode, and out of the solution at the cathode, while the other reaction is represented by the equation $Ni + CuCl = NiCl + Cu$. The energy corresponding to the first electrochemical action is zero, the energy corresponding to the second electrochemical action is given by thermochemical data. Now, if a certain number of coulombs pass through the cell and a certain proportion of the same dissolves copper from the anode while the balance dissolves nickel from the anode, then the energy corresponding to the electrochemical action of the first portion of coulombs is zero, while the energy of the second portion of coulombs (those which dissolve nickel) can be calculated from thermochemical data. The total energy corresponding to the electrochemical action in watt seconds is therefore equal to that consumed by the coulombs which dissolve nickel and deposit copper. If we divide this total energy in watt seconds by the total number of coulombs which were passed through the cell, we get the volts corresponding to the total electrochemical action. This is what Dr. Richards calls composite voltage, since it refers to two distinctly different electrochemical actions.

Another case of great practical importance is the simultaneous deposition of a metal with the evolution of hydrogen. In this case we have again two distinct actions and calculate the energy corresponding to each action separately. By adding them we get the total energy, and by dividing the latter by the total number of coulombs we get the voltage corresponding to the total action.

An interesting calculation which may be drawn from this theory is that the composite voltage depends, not only on the nature of the two reactions which go on simultaneously, but also upon the extent to which the one reaction prevails over the other. The generalization of the rule to more than two simultaneous electrochemical reactions is, of course, simple.

In the discussion Mr. Smith emphasized that Prof. Richards' theory seems to contradict the common assumption that a distinct voltage is required for the discharge for each kind of ion. Dr. Richards replied that this assumption is based on the supposition that only one single electrochemical action is going on, and is then a consequence of the energy principle; in the case of a mixed action one must proceed in the calculations as was shown in his paper.

Formation of Hypochlorite.

A paper on this subject was presented by Mr. S. S. Sadtler, who described experiments made by him to determine the following relations: First, the influence of alkali on the total amount of hypochlorite formed in the electrolysis of solutions of common salt; second, the influence of different concentrations of sodium chloride in the solutions; third, the influence of current density on the yield of hypochlorite; fourth, the influence of anodes of different materials on the yield of hypochlorite; fifth the chemical action of anions on some of the anodes used.

In general it was found that very small amounts of alkali, such as one or two grams per liter, very much lessened the amount of hypochlorite formed with some concentrations of salt, and with other concentrations it prevented its formation entirely. Higher current densities favored the yield of hypochlorite and increasing amounts of salt in solution increased the yield up to a certain point, and then it fell off with stronger solutions. Peroxide of lead electrodes gave the best yield, next came platinum and iron, while nickel gave the lowest yield.

In the discussion which followed, Dr. Gahl referred the observations made with different electrode materials to the different overvoltages at the various electrodes.

Theory of Electrode Voltage.

A paper on this subject was presented by Dr. Rudolf Gahl. While the final results which he arrives at are the well known formulas of Nernst, the method by which he reaches them is quite novel, being based on the modern theory of electrons.

Helmholtz has shown that some electrochemical processes are easy to explain if one assumes electricity as a kind of matter, and regards it as a substance composed of atoms of very small atomic weight. As Nernst explains in his "Theoretical Chemistry," the law of Faraday is thereby reduced to the chemical law that compounds are always formed in certain proportions or simple multiples of it. The recent researches on cathode rays have also shown the great fruitfulness of Helmholtz's idea. It was even possible to determine the atomic weight of the electrical atom. The successful application of the atomic theory of electricity suggests to make a further step by trying to regard the generation of the electric current in a galvanic cell in a purely chemical way.

It must be assumed that the electrons are soluble in metals, and that accordingly there is a tendency to distribute them equally in the solvent. In other words, if we apply this to solutions, osmotic pressure drives the electrons from a higher pressure to a smaller one, but in electrolytes electrons only exist bound to other atoms, in the form of ions and other molecules.

According to these ideas the dissolution of zinc in the Daniell cell is a dissociation of a Zn atom (with two positive and two negative electrons) into a Zn ion (with two positive electrons) and two negative electrons. The only difference from a common chemical dissociation is that one of the dissociation products is only soluble in one phase, the other product in the other one. Otherwise it is quite the same, as, for example, the dissociation NH_4Cl into NH_3 and HCl. In this system addition of NH_3 lowers the pressure of HCl, and addition of HCl the pressure of NH_3. In just the same way, in the other case addition of zinc ions lowers the pressure of the electrons, whereas an increase in the pressure of electrons in the metallic phase lowers the osmotic pressure of the zinc ions near the electrode. The same relations as for a common dissociation equilibrium may, therefore, be applied here. If we do not consider the variation of the equilibrium with the temperature the equation may be written:

$$p^{z}_{(-)} = \frac{k_1}{p_{Zn^{++}}}$$

This equation shows how the osmotic pressure of the electrons varies with the concentration of the zinc ions.

In order to build up a cell it is necessary to have two electrodes. To get a Daniell element a copper electrode in copper sulphate solution has to be used as second electrode. For the equilibrium between copper ions and electrons an equation of the same kind will exist.

$$p^{z}_{(-)} = \frac{k_2}{p_{Cu^{++}}}$$

If the electric current in the metallic circuit is regarded only as a movement of electrons, the direction of the current will depend on which of the $p_{(-)}$ values is the greater one. The e. m. f. is the work that can be done by the electrons falling down from the higher osmotic pressure to the lower one.

In applying the laws of dilute solutions it is found

$$E = R\,T \ln \frac{p_{(-)1}}{p_{(-)2}}$$

or if the above derived values are substituted

$$E = \frac{R\,T}{2}\left[\ln \frac{k_1}{p_{Zn^{++}}} - \ln \frac{k_2}{p_{Cu^{++}}}\right]$$

This is the formula which was derived by Nernst a long time ago. It is interesting that it is possible to reach the same formula by only regarding the electromotive process of a cell in a purely chemical way, and it seems to indicate that the assumption made was right, that it is allowed to make calculations with a negative electron in the same way as with any other atom. But if this is right, we have to change some of our electrochemical ideas. For example, there would be no absolute potential at all, for, as a copper ion is then a chemi-

cal compound different from metallic copper, we cannot assume that metallic copper is in equilibrium with a certain concentration of copper ions, but have also to consider the electrons, which must have a certain osmotic pressure dependent on the concentration of the copper ions to make the equilibrium complete.

Application of Thermodynamics in the Calculation of Electromotive Force.

A brief note on the subject was presented by Mr. E. W. Smith on the nature of the phenomena which are commonly comprised in the term overvoltage. He considers that the well-known Gibbs-Helmholtz equation takes account of the overvoltage in the second term which contains the temperature coefficient of the e. m. f.

Dr. Gahl doubted whether this conclusion is correct, since the Gibbs-Helmholtz equation is based on the assumption that the discharge or charge of a cell is absolutely reversible. The question thus resolves itself into the other one whether the evolution of gases at an electrode is absolutely reversible in thermodynamical sense. If it is then the phenomenon of the overvoltage must appear in the second term of the Gibbs-Helmholtz equation. It would be interesting to collect the experimental data relating to this question.

STRUCTURE AND TENSION.

By Oskar Nagel, Ph. D.

It was stated in an editorial of the February issue of Electrochemical Industry that, regarding electrodeposition, the structure of a metal is possibly playing a more important part than its tension.

I will try to show now that the structure of a metal is dependent on the location of the metal in the tension series, and it is a matter of opinion if the one or the other is estimated as of higher importance. The "tension" is the more general expression having a wider scope, and is therefore to be preferred.

In looking over the tension series we notice that in going from silver to copper, lead, iron, zinc, aluminium and magnesium, we are going constantly from the (technically) more metallic to the less metallic metals, from the more passive to the active metals, and from metals with low dissolving tension to metals of high dissolving tension. The structure is changing accordingly.

It is known (Nernst, *Theoretische Chemie, Dritte Auflage*, page 679) that the decomposition of water by metals is increased

1. With the increasing pressure of the hydrogen ions.
2. With the increasing dissolving tension of the metal, or with decreasing osmotic counter-pressure of the ions of the metal.

Therefore, for the electrodeposition of metals out of salt solutions,

I. The concentration of the ions of the metal A has to be as high as possible, and

II. The concentration of the hydrogen ions B has to be as low as possible.

As now in water solutions the concentration of the hydrogen ions B is decreasing proportionally with the increasing concentration of the hydroxyl ions C it is necessary for the electrodeposition to have AC as large as possible. According to the law of solution this is limited by the solubility of the hydroxide of the metals. The impossibility of electrodepositing aluminium or magnesium out of water solutions is therefore explicable, not only by the high dissolving tension of these metals, but also by the exceedingly low solubility of their hydroxides.

As the conditions I. and II. are getting more and more unfavorable in going from silver to magnesium, the difficulty of electrodeposition is increasing accordingly.

THE THEORY OF ELECTRODE POTENTIAL.

By Woolsey McA. Johnson.

In preceding articles (Electrochemical Industry, vol. I., 1903, pp. 373, 454, 537) we endeavored to give some account of the experimental facts of electrode potential, to show what it was, how it could be measured, and the standards against which it was measured. This article concludes the series by developing the theory along two lines, viz.:

(1) Thermodynamics.
(2) Osmotic Pressure.

Heretofore we aimed at novelty of treatment and illustration. Now, we will follow quite closely the lectures given by Prof. W. Nernst in the years 1899-1900.

The theory of electrode potential developed along the lines of thermodynamics is independent of any special theory or hypothesis which describes the supposed mechanism of the energy changes. It is immaterial whether the energy takes the form of osmotic energy or of "solution energy." The laws of thermodynamics hold good whatever the mediums be.

It has been aptly said, that thermodynamics is "energy-book-keeping." We measure first how much energy a system had. Next we measure how much energy was added to the system, how much energy it gave up in form of useful work, how much energy it gave up in useless heat in the operation. Finally, we measure the energy at the end of operation. By equating these with the proper signs, the sum is equal to zero. In reality thermodynamical calculations resemble an "energy-balance-sheet."

The first law of energy is expressed indefinitely in the above paragraph. Exactly it can be stated as follows. The decrease in total energy is equal to the work done by the system, less the heat supplied the system from the outside surroundings, or

(1) $U = A - Q,$

where U = decrease in total energy
A = work done by system
Q = heat given to system.

As a corollary to this law, which is a mathematical statement of the law of the conservation of energy, we have the law that there is always a constant relation between different forms of energy, as thermal, electrical, mechanical. For instance, we know by experiment that 772 foot-lbs. = one British thermal unit.

The gist of the second law of thermodynamics is that "a person cannot lift himself by his boot-straps." More exactly, the maximum amount of useful work any system can perform depends on two factors, and is mathematically expressed by the equation,

(2) $dA = Q \frac{dT}{T}$

Any process by which the work is done in accordance with the above formula is styled a "reversible" process. The maximum amount of work is done when a "reversible" process is carried on.

A third law is a combination of the first two.

(3) $A - U = T \frac{dA}{dT}.$

for by (1) $A - U = Q$, and by (2) $Q = T\frac{dA}{dT}$

We will now assume in the electrochemical system anode-anolyte-catholyte-cathode, that all the potential energy of chemical separation is changed into electrical energy when the cell is closed through an outside resistance. For purposes of calculation, the Daniell cell will be taken as it is the classical example. This special assumption is called "Thomson's rule," for it was first made by Sir William Thomson, now Lord Kelvin. It is not exactly correct, but still in many cases gives remarkably close approximations.

The e. m. f. of a Daniell cell varies with the concentration. For convenience in calculation we will take it as 1.10 volts. Let us connect it with an outside resistance of 1.10 ohms. On closing the circuit, by Ohm's law, exactly one ampere will flow, if the resistance of the cell is zero. If the resistance of the cell be made very small, say 0.005 ohms, by constructing a cell of 200 times the electrode area of the usual cell, the loss in internal resistance can be neglected.

If the current flow for one day, the energy absorbed by external circuit is given by the equation,

$A = E \times C \times 24 = 1.10 \times 1.00 \times 24 = 26.4$ watt hours.

Now measurements of the relation between electrical energy and heat have been very carefully made by Prof. Rowland and others. For purposes of this calculation, the value 1 watt hour = 0.87 kilogram calorie is sufficiently accurate. This means that a 50-watt incandescent lamp will raise one liter of water (which weighs nearly a kilogram) 43.5°C. in one hour, if the water surrounds the lamp and is protected from radiation by mineral wool or asbestos, so that no heat is lost by radiation.

Consequently the heat developed by the Daniell cell in 24 hours is,

$A = 26.4 \times 0.87 = 23.0$ calories.

Twenty-three calories is enough heat to raise 1 kilogram of water 23° C. Therefore, if we had a Daniell cell as large as a wash-tub whose resistance would be negligible with leads of No. 12 wire running through a beaker of water, containing one liter of water, we might expect that the water would become hotter at the rate $\frac{23}{24}$ C. per hour, provided our assumptions are true and no heat is lost by radiation.

Now, Faraday's law demands that in the 24 hours one ampere will dissolve a definite amount of zinc and precipitate a definite amount of copper. Foster's Handbook gives the values for one ampere hour 1.1855 grams copper, and 1.2193 grams zinc. Taking these values as 1.19 and 1.22, which is accurate enough for this calculation, we have in our 24 hours' run, deposited 28.6 grams of copper, and dissolved 29.3 grams of zinc.

Chemistry teaches that 65.5 grams of zinc will precipitate 63.0 grams of copper out of a copper sulphate solution with the evolution of 50.13 calories of heat. The reaction proceeds very energetically with zinc dust and is quantitative. As a matter of fact it is a reaction often made use of in analytic determinations of copper. Julius Thomsen, the great Danish thermochemist, determined this by the difference of the reactions,

Zn + O + SO_3 =	106.090	calories.
Cu + O + SO_3 =	55.960	"
	50.130	calories.

It can be parenthetically remarked that Thomsen was extremely practical in his ideas. His design of furnace for calcining cryolite is in use to-day in this country.

In our Daniell cell we have 29.3 grams of zinc dissolved instead of 65.5, consequently the heat evolved in the beaker of water, our rough calorimeter, is

$$A = \frac{29.3}{65.5} \times 50.13 = 22.4 \text{ calories.}$$

We had calculated from the electrical equivalent of heat, and the e. m. f. of the Daniell cell 23.0 calories. Considering the limits of error in the measurement and remembering that the Daniell cell has a different e. m. f. for different solutions, varying from 1.08 to 1.11, the agreement is surprisingly close.

However, refinements in measurement can be made and the solutions made so that they represent the actual solutions used by Thomsen in his thermochemical experiments, the value of e. m. f. is then 1.093 volts, corresponding to 25.263 calories,* while the reaction gives only 25.055 calories. The difference is 0.208 calorie.

*Nernst, Theoretische Chemie, p. 650.

With other cells this difference is much larger and can even amount to 30 or 40 per cent instead of less than one. So we see that Thomsen's rule is only an approximation, and that there must be some other factor in the equation which does not enter into the equation.

It was deduced by von Helmholtz and W. Gibbs that Thomsen's rule only held when the e. m. f. of the element varied but little with the temperature. A fixed relation between the temperature-coefficient of the e. m. f. of the cell and the discrepancy from Thomsen's law was deduced theoretically. This has also been proven experimentally. Cells which give a higher e. m. f. than Thomsen's rule calls for have a positive temperature coefficient, while those that have a lower e. m. f. have a negative e. m. f. The former absorbed heat from the surroundings in electrolysis, while the latter evolved heat. Obviously this change is comparable in a rough way to heat absorbed when ice is melted or water is boiled.

This relation is the law known as the Gibbs-Helmholtz equation.

$$A - U = T\frac{dA}{dT}$$

The relation can be worked out for the special case of the Daniell cell. Heat of chemical change less external work = — H (H being amount of heat the system exchanges with the surroundings.)

$$Q - E = -H.$$

Let us take a Daniell cell at a temperature T and discharge it until one coulomb of electricity has passed through it. The electrical work done is E joules. The reaction heat is Q. The temperature is now raised to T + dT, and the cell charged with an outside source of electricity dissolving copper and precipitating zinc, the e. m. f. at temperature T + d T being E + dE. When one coulomb has passed, the electrical work done is E + dE joules. Allowing the cell to cool to T we have everything in condition to start.

We have then, by the second law of thermodynamics,

$$dE = H\frac{dT}{T} - (E \quad Q)\frac{dT}{T}, \text{ or } E - Q = T\frac{dE}{dT}$$

Applying this equation (the Gibbs-Helmholtz equation) to the Daniell cell, we have,

E =	25.263	calories corresponding to 1.093 volts.
Q =	25.055	calories, Thomsen's value.
E — Q =	0.208	calories.

T = 273°

$\frac{dE}{dT}$ = 0.000034 volts (found by experiment).

$E - Q = 0.000034 \times 23.110 \times 273.214$ calories.

This agrees very closely with value 0.208 calorie, obtained by the other calculation. Numerous other cells have been tested and their e. m. fs. found to agree very closely with that calculated by Gibbs-Helmhotz equation.

As remarked in the opening of this article, the theormodynamical theory is general. It does not explain the mechanism. It simply analyses the energy changes. The osmotic dissociation theory does more than this. It gives an account of the means by which these changes take place.

The osmotic theory assumes that a dissolved substance behaves exactly as if it were a gas, and the solvent a vacuum. The osmotice pressure is found to follow the law $P = \frac{RT}{V}$.

When sugar dissolves in water there must be some pressure which drives the sugar molecules in solution. This is called "solution-pressure." The osmotic pressure opposes this solution pressure. This pressure is due to an attraction between the solute and solvent. Dissolved substances lower the freezing point and raise the boiling point, according to definite

laws. These laws state that equivalent molecular parts will produce the same effect in lowering freezing point, etc.

Now, when the formulas found otherwise to be true for lowering freezing point, and raising the boiling point, are applied to solutions of such salts as sodium chloride, it is found that in each case the laws only hold good unless we assume that the number of molecules have been increased in some way.

This discrepancy shows remarkable similarity with discrepancies in the measurements of the vapor density of ammonium chloride. On volatilizing this salt the pressure noted is much larger than that deduced from the laws of Boyle, Charles and Avogadro. This leads to the deduction the ammonium chloride is broken up into its constituents ammonia and hydrochloric acid, thus

$$NH_4Cl = NH_3 + HCl.$$

For an extended account of the experimental facts and deduction from them, the reader is referred to Jones' "Elements of Physical Chemistry," p. 60 et seq. The dissociation is caused by heat.

Analogously, it is taken that sodium chloride in aqueous solution is broken up into a sodium ion and a chlorine ion, the charge of electricity modifying their chemical properties. The equation in this case is

$$NaCl = Na\cdot + Cl'$$

This reaction is not complete, but becomes more complete as the dilution increases. At infinite dilution it is theoretically complete. The electrolytic dissociation is caused by the high dielectric constant of water.

Of a 100 molecules of sodium chloride dissolved in water we will say that 50 are dissociated and 50 undissociated. The total number of particles exciting pressure is now 150, because the basis of the whole theory is the assumption that an ion exerts just as much pressure as an undissociated molecule.

Each ion, however, can carry just so much electricity depending on its chemical valence, and each ion offers a certain amount of friction depending on its nature to the solution. It may be said that each ion has a specific carrying capacity for electricity. Thus, the electrical conductivity is proportional to the sum of free ions in the solution.

From the electrical conductivity of solutions the number of dissociated molecules can be calculated. For further details of this, including Kohlrausch's law, etc., the reader is referred to the "Theory of Electrolytic Dissociation," by Jones. Suffice it to say that there is a very close agreement between the different dissociation constants calculated from the electrolytic conductivity, freezing-point method, boiling-point method, and osmotic pressure.

Now we will return to electrode potential. To account for any material movement we must have recourse to the conception of pressure. The pressure which causes water to change into vapor is termed vapor-pressure. That which causes sugar to dissolve in water is termed solution pressure. Accordingly, the pressure which causes zinc to dissolve as anode is termed electrolytic solution pressure. There is always an electrical displacement along with the material displacement.

The nature of electrolytic displacement is essentially different from electrical displacement in a metal wire. In the latter case the "electrons" are moved from molecule to molecule without any movement of what is denominated "sensible matter." In the former case matter actually moves with the "electrons."

The following analogy was told me by Mr. William Stanley some twelve years ago, and has been, on many occasions, a great help in giving a concrete conception of the difference between the two kinds of electro-conduction.

In metallic conduction the electrons are passed along, as coal would be passed along a line of men with shovels. The men with shovels are the molecules of metal. In electrolytic conduction each man has a wheel-barrow of the same capacity, or an even multiple thereof if he is stronger. The coal is actually pushed along in these wheel-barrows.

Similarly each ion can carry 96,540 coulombs of positive or negative electricity, or an even multiple thereof. In a preceding paragraph, it was noted that each ion had its own specific constant of electrical conductivity, the sums of which for all anions and all cations was the conductivity of the solution. These constants for ions are intimately connected with the so-called "transport numbers" (a rendering into English of the word Ueberführungszahl).

If finely divided chalk is suspended in a tall jar of water, the particles will fall slowly to the bottom. The motion is slow and takes place at a definite velocity if the particles be of the same size. The "damping" effect of the water is so great that the velocity does not increase, but is practically constant. Like conditions hold in the pull of the field of electrostatic stress between two electrodes on the charged ions. This stress would pull them through at an increasing rate if they were free to move. But the electrolyte offers so great friction to the movement, that the displacement is directly proportional to the time. There are very few analogies more complete than that between the falling of finely divided particles through a medium offering great friction and the flow of cations to cathode and anions to anode.

The above is but a brief epitome of the theory of electrolytic conduction. It is impossible within the limits of this article to do more than to explain the facts of the previous articles in the light of the dissociation theory.

The electrolytic solution pressure of any metal is termed P. The non-metals, oxygen, chlorine, bromine, etc., have also an electrolytic solution pressure tending to make them anions. In the case of metals with a high solution pressure, a certain amount of atoms are thrown off from the metal into the electrolyte, carrying a certain charge. This leaves metal negatively charged. The process continues until the attraction between the negatively charged metal and positively charged solution is so great that just as many ions jump back to the metal as are thrown out from the metal. The so-called "double-layer" is now in a state of equilibrium. However, if there is a zinc electrode, and the electrolyte originally had possessed zinc ions, it is clear that the equilibrium would be reached much quicker, because there is already a pressure on the double layer tending to deposit ions on the metal. This pressure is due to the osmotic pressure of the ions, and is written p. In any electrolysis we are thus carrying metallic ions from a pressure P to a pressure p, or the reverse if the metal is deposited.

The laws of gaseous pressure hold for osmotic pressure, and we are really distilling matter from one pressure P to a pressure p. The laws of gas-pressure are contained in equation $pv = RT$. Mechanics teach that the work (A) done in passing matter at constant temperature from one pressure to another is thus given by

$$A = \frac{RT}{c} \ln \frac{P}{p}.$$

In the previous articles we noted the experimental fact that metallic electrolysis was reversible at small current densities. This work (A) is the maximum amount of work that can be done from the pressure P to pressure p provided the process is reversible and temperature constant.

When we allow the electrolysis to continue until one coulomb has passed from cathode to catholyte the work done is expressed by a general equation:

$$A = E\,C\,T$$

Where A = watt seconds or joules.

E = e. m. f. in volts.

C = current in ampere.

T = time in seconds.

As CT is equal to unity, we have simply: $A = E$, then as A from first equation $= \frac{RT}{c} \ln \frac{P}{p}$, we g .

$$E = \frac{RT}{c} \ln \frac{P}{p},$$

Where R = gas constant.

T = absolute temperature.

C = number of coulombs to deposit one gram of hydrogen (96,540)

changing to Brigg's logarithus and putting in values for

$$R, T, C, E = 0.0577 \log. \frac{P}{p}.$$

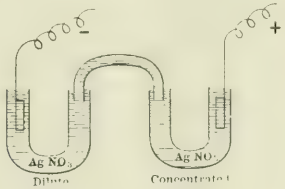
We now have an exact expression for the electrode potential of any metal dipping in a solution of its salts. It may be objected that this looks very pretty in theory, but cannot be proven. It was put to the test of experimental proof about fifteen years ago by Prof. Nernst, by a very simple experiment.

For the same metal P is a constant. Balancing one solution pressure against another, we have,

$$E_1 - E_2 = 0.0577 \log. \frac{P}{p_1} - 0.0577 \log. \frac{P}{p_2},$$

$$\text{or } e = 0.058 \log. \frac{P_2}{p_1}.$$

This formula is the formula for the e. m. f. of a so-called concentration cell.



CONCENTRATION CELL.

Two strips of silver dip into a solution of silver nitrate of different concentrations in two U-tubes. The two U-tubes are connected with a siphon of solution. Solution in I. is dilute, in II. concentrated. The concentrations should be so selected that the ions are ten times as numerous in the concentrated solution as in the dilute. Thus, the pressure of II. is ten times as great as that of I. We have seen that the osmotic pressure opposing the electrolysis depends on the ions and not the undissociated molecules. The logarithm of ten is 1. Consequently, if we neglect the e. m. f. at the meeting of the two solutions, e = 0.0577. The value found was close to this value. Making all corrections, the error was as small as could be expected. Decreasing the concentration in I., until the ratio is 100, we find the experimental value to be close to 0.116 volt.

So having found that the e. m. f. is a measure of the concentration of ions by the logarithmic ratio of the pressures (concentration being proportional to pressure) it is possible to measure the concentration of the silver ions of unknown silver solution if we measure the e. m. f. against a standard silver electrode.

For example, the combination,

Ag, AgCl, $AgNO_3$.1N, Ag
nKCl

gave 0.51 volt. Therefore, $C_1 = 1.10 \times 10^{-10}$.

Direct measurement by chemical analysis gave 1.21×10^{-10}. The following† will explain some of the facts about concentration cells.

We know, for example, that it is possible to reverse a Daniell cell by simply adding a strong solution of KCN to the catholyte; that this will give a steady discharge of a considerable current, with the copper dissolving and the zinc being precipitated.

† Electrochemical Industry, February 1903, p. 212

By Nernst's equation we have

$$E = e_1 - e_2 = 0.058 \log. \frac{Pzn}{pzn} - 0.058 \log. \frac{Pcu}{pcu}$$

neglecting the small e. m. f. at the contact of the solutions.

Now, when we add KCN to catholyte, we do not affect Pzn or pzn or Pcu, but we reduce Pcu to a small value. In other words, we have decreased the ionic pressure of copper to an amount so small that its own solution pressure is sufficient to push the copper ions continually into solution. Copper hydrate is, for analytical purposes, considered insoluble, but the solution pressure of $Cu(OH)_2$ with regard to the copper ions is large compared to that of the potassium copper-cyanide that is formed.

Similarly, we find that in a "concentration cell" that reagent which produces a chemical action in precipitating a dissolved salt or in dissolving a precipitate gives a higher e. m. f. against the standard electrode.

To be concrete, the cell

Ag|$AgNO_3$0.1n|AgClnKCl|Ag gave 0.54 volt.
Ag|$AgNO_3$0.1n|$AgNO_3$nNH$_4$OH|Ag gave 0.54 volt.
Ag|$AgNO_3$0.1n|AgBrnKBr|Ag gave 0.64 volt.
Ag|$AgNO_3$0.1n|$AgNO_2Na_2S_2O_3$|Ag gave 0.84 volt.
Ag|$AgNO_3$0.1n|AgIKI|Ag gave 0.91 volt.
Ag|$AgNO_3$0.1n|$AgNO_3$KCN|Ag gave 1.31 volt.
Ag|$AgNO_3$0.1n|$AgNO_3Na_2S$|Ag gave 1.36 volt.

We can see that each reagent in the electrochemical series produces a chemical action on the compound just below it. For instance, AgCl is soluble in NH_4OH, while AgBr is precipitated by the action of KBr on the soluble ammoniacal silver salt. The same is seen through the series $Na_2S_2O_3$, KI, KCN, Na_2S. This knowledge throws a Nernst light on the subject. We find in the ionic theory of concentration cells a satisfactory explanation for the perfect correspondence between chemical behavior and the electrochemical quantity, e. m. f. against a standard electrode. The same correspondence is found true in most concentration cells measured. For further particulars, the reader is referred to Nernst's classical researches on concentration cells, in the *Zeit. f. Phys. Chemie.*, 1889, to Le Blanc's "Elements of Electrochemistry" (translated by W. R. Whitney), p. 178.

It is therefore quite easy to understand why NH_4OH dissolves AgCl, etc. It is that a double salt is formed by the two, which has such a small pressure of silver ions that the reaction proceeds until equilibrium is reached. Looked at broadly, it is little different from the rising of heated air or the flowing of water down hill. All three actions consist in matter flowing from high pressure to low pressure. The difference lies in us. Water pressure and air pressure are familiar to our minds, but ionic pressure is a new conception.

Now, if we could determine the equilibrium point of the reaction, Zn + $CuSO_4$ $ZnSO_4$ + Cu by analytical data we could determine the e. m. f. of the Daniell cell by the equation

$$E = 0.057 \log. K$$

where K equals the equilibrium constant of the law of mass action.

This is exactly the same as former equation for e. m. f. of Daniell cell, if

$$K = \frac{c_1 c_2}{c_3 c_4}.$$

Still one more phenomenon of electrode potential can be noted. This is the fact that with only very few electrodes is the decomposition of an electrolyte with formation of gas a reversible process. There is always a certain excess of potential with electrodes that exhibit the Casparian "overvoltage." This voltage is effective in making reductions at the cathode and oxidations at the anode. For organic electrochemical methods it has been especially valuable.

In starting these articles on electrode-potential, which is one of the most important divisions of electrochemistry, it had been

the original intention to extend the series over the entire subject and to give such conceptions of the experimental facts which had been found useful in practical work. The aim was to serve the maximum number of readers, chemists, electrochemists and electrical engineers. It is to the regret of the writer that other work has a greater "electrode-potential" than this, with the resultant displacement of the weaker. Needless to say, the crystallizing of these articles were a source of benefit and pleasure, even though done in odd moments of a busy year. It is hoped that the readers have likewise shared in this benefit.

THE CYANIDE PLANT AND PRACTICE AT THE YMIR MILL.

In a paper presented to the American Institute of Mining Engineers, Mr. Edwin C. Holden gives a very interesting account of the cyanide plant and practice at the Ymir Mine, West Kootenay, B. C. Some results obtained by the author in his previous investigation of the situation, and some features of the practice, adopted at his advice, are quite novel.

The vanner-tailings during the quarter ending January, 1903 (and all the figures here given, unless otherwise stated, are for that period), assayed 0.0882 ounce gold and 1.051 ounces silver per ton; lead, 1.3; and zinc, 2.2 per cent. Of this material, 65 per cent would pass a 100-mesh screen.

The vanner-tailings being of comparatively low grade, Mr. Holden felt himself practically confined to the adoption of the system of direct filling and percolation; and, as slimes-treatment was not at the same time to be provided for, the object was to treat as large a proportion of the slimes as possible with the sands; or, in other words, to make charges having the lowest practicable rate of percolation. This minimum rate is usually stated as 2 inches per hour.

It is also a current conception that a much larger proportion of slimes can be handled in an intermediately-settled charge than in a directly-filled one. To determine whether this possible difference in tonnage was important enough to justify the increased cost of installation and operation of a plant with settling-vats was an important problem, which was decided in an experimental plant, consisting of two 35-ton leachers, 5 ft. deep. One leacher was charged direct from a Butters' distributor, which was fed by the bottom-discharge of a pointed box carrying the vanner-tailings from twenty stamps. The box got rid of excess water and a little of the finest slimes. The second leacher was charged from a two-compartment box in which the vanner-tailings were settled, the sands being dropped from the compartments alternately as filled, and shoveled in the leacher as in ordinary intermediate filling-plants.

The results were rather unexpected, it being found that direct filling, when properly done, not only leaves a charge in as good condition for treatment as the intermediate method, but renders it possible to treat a larger proportion of the slimes. It is suggested as an explanation that in a charge settled under water the grains of sand are free to arrange themselves most compactly, with a minimum of voids, and the slimes are held near where they originally settled, because the interstitial currents are not marked enough to disturb them; whereas, in charges shoveled into a vat with less than 15 per cent of moisture, the voids are a maximum, and the slimes which originally coated each grain of sand are washed off and settle through the charge, and, thus segregating, prevent uniform percolation. The fact that direct-filled charges never pack or settle more than 1 per cent, while indirect ones frequently contract over 10 per cent, during treatment, tends to confirm this view.

The final plant is located half a mile from the stamp mill and 300 feet vertically below it. The vanner-tailings are carried to the plant by a box-launder 6 by 8 inches in section, and the excess of battery- and vanner-waters allows of a minimum grade of slightly under 5 per cent. At that grade, and with 1-inch riffles set 5 inches apart in the bottom of the box, the durability even of the local soft hemlock and cedar lumber used is quite satisfactory.

To make the required fall of 300 feet to the plant, a series of drop-boxes is inserted where the topography is favorable; and a 12-inch sand-pocket at the bottom of each drop, to prevent wear, should also be an efficient saver of escaping amalgam or mercury.

The tailings enter the top of the storage-solution room; and when, as in the period under consideration, from forty to sixty stamps are running, the classification is done in two boxes, the first being 18 by 24 inches wide by 18 inches deep, with two vertical sides and false ends sloping 60° to a 0.5- by 24-inch slot, under which hydraulic currents can be applied. This box settles only the coarse sands, which are drawn off through a 2-inch nipple into the charging launder. The second box is pointed, 3 feet 6 inches in width and depth, and 7 feet long, with a 3-inch outlet. A plug-valve in this outlet, in combination with the hydraulic current in the box, regulates the speed of the distributors, while maintaining the same separating action in the box. The overflow from this box, carrying about 60 per cent of the water and 20 per cent of the total tailings, is run to waste. This overflow should all pass a 100-mesh screen, and is mostly impalpable material.

All of the vats and tanks, except the sumps, are of steel. The leachers, 32 feet in diameter by 6 feet deep, are on timber foundations with masonry footings. Caps and sills are paralleI, an arrangement which renders jacking-up easier than the usual right-angled structure. Bents and posts are spaced 4 feet between centers, and the bracing does not extend above the post, the shimming being done between posts and caps. On the caps are 4- by 8-inch joists spaced 18 inches between centers. There is no flooring on any of the vat- or tank-joists, and there is headroom under them all, so that leakages occurring in the plant cannot be unknown or inaccessible. The vats are fitted with top annular-overflow launders; and, to preserve a level rim, a soft wood strip, projecting above the edge of the vat, is fastened with stove-bolts to the side-plates, the joint being calked with oakum. Any settling of the vats which is insufficient to require jacking-up from below can thus be easily rectified, just as with tongue-topped wooden vats.

The distributors are of the usual type, and have twenty 1.5-inch arms. This area of discharge-openings, with our quantity of tailings, never allowing any head to accumulate in the distributor-hopper, renders uniform distribution difficult. The slightest throw of the stream from the charging drop-box off the center of the hopper results in uneven charging, most of the slimes going to the low side of the vat. Many devices were tried to remedy this, and to prevent twisting of the drop-stream, which motion also has a classifying effect; and the last and simplest plan was successful. The drop was made square; and inside the lower end of it an iron strip was fastened to each side. The square drop prevents twisting, and to throw the stream toward the low side of the charge small wedges were driven under the iron strips, as needed.

These details may seem trifling; but when the object is to treat the maximum quantity of slimes by percolation they will be found of prime importance in obtaining a uniform charge.

Where there is enough headroom to give distributor-arms 3-inch grade per foot, arms of 1-inch diameter, or even smaller, could be used without danger of clogging. This would be an improvement upon the usual form, which has 1.5-inch arms at 1.5-inch grade; for it would approach the ideal conditions requiring a maximum number of arms fed from a full hopper.

Continuous, uniform charging is essential to make a good charge; hence, so far as possible, stamp-mill hang-ups were made between charges. When, however, an emergency hang-up was made with a charge incomplete, a gentle hydraulic current was started under the filter in the vat; the water-feed to the distributor was increased; and, when charging was recom-

menced, the settlers were run with a strong hydraulic current for a few minutes, allowing only the coarse sands to settle. Despite every precaution, however, a slime-layer will mark in the charge every mill hang-up of over ten minutes' duration.

The classification of values in charges and overflows was marked, the average assays and screen-tests for the year being:

	Au. Oz. Per Ton.	Ag. Oz. Per Ton.	Through 100-Mesh. Per Cent.
Vanner-tails	0.0838	1.008	64.86
Charges	0.0931	0.637	50.70
Overflows	0.0621	1.878	98.90

The high silver in the overflow is due to its association with galena in the slimes.

The system of classification was crude; and if the plant were pushed to its full capacity, close hydraulic classification, yielding a clean, quick-percolating charge, would be necessary; but, as run at this time, the system was very satisfactory, for it settled and treated a total of 70.1 per cent of the vanner-tailings. When they were treating oxidized ore, charges could not be successfully treated that carried over 45 per cent of fines.

With all the stamps dropping, a vat was filled in from twenty-eight to thirty-two hours; but during the last quarter of 1902 it required from forty-eight to sixty hours. The experimental work called for five days' treatment; but, with the reduced crushing, they increased the proportion of slimes settled, and treated charges as long as our capacity allowed,—the average time of treatment being 10.5 days. A normal charge was 185 tons, dry weight.

The acid tests seem, in the case of the Ymir tailings, to be worthless as an indicator for the use of lime. The ordinary tests for latent acidity called for over one pound of lime per ton. Phenolphthalein indicated more. They used 200 pounds to the charge for a while, until the zinc boxes grew so foul that dried precipitates assayed under 1200 ounces of total fine bullion per ton. The methyl-orange indicator was more satisfactory. It called for less than 0.5 pound of lime per ton. But the final practice, which gave the best results, was to use less than .0.1 pound per ton, and apply it in 5-pound lots, the last lot going on with the final dose of strong solution. The cyanide-consumption was thus reduced over 10 per cent; and the zinc-box crude precipitates rose in grade to over 5300 ounces per ton. In treatment, the final filtrates became very cloudy when they titrated between 0.1 and 0.05 per cent KCN; and the small addition of lime, just before starting weak treatment, tended to keep the slimes coagulated and the filtrates clearer.

Vacuum percolation was soon discarded, as it gave a very dirty filtrate and packed the charges, so that the final rate of percolation was slower, even with the vacuum, than it would have been if unassisted throughout.

The routine of treatment was as follows:

After leveling and adding dry lime, two 5-ton doses of weak solution (between 0.1 and 0.05 per cent KCN) are successively given. When these have disappeared they are followed by four or five 10-ton doses of strong solution (0.2 per cent) at five-hour intervals. There is no trace of cyanide in the filtrate for six hours after the first application of weak solution, and there are no values until after fifteen hours. After 40 or 50 tons of strong treatment the charge is drained six hours, when the filtrate has almost ceased, and titrates 0.04 to 0.07 per cent KCN. Twenty tons of strong solution are now run in under the filter. It requires from six to eight hours to run this in without channeling the charge, and when it is all in, if drainage has been sufficient, there will not be more than 5 inches of solution on top of the charge. After soaking from three to six hours, the charge is drained, and a 10-ton top treatment follows. Top and bottom treatments thus alternate until 160 tons of strong solution have been applied. Then follows weak treatment, applied on top in 5-ton doses as rapidly as it disappears, to a total of 40 or 50 tons. This is followed by wash-solution (0.05 per cent to trace KCN), 40 tons; and this, by water as required, to preserve the balance of solutions or secure low end-filtrates. No solution is run to waste, other than what is lost as moisture in the residues.

The adoption of bottom-treatment had a marked effect. During the first six months' operating, when only top-treatment was used, the gold-extraction gradually fell off from 70 to less than 50 per cent; and assays from the bottom of the charges were discouraging. When the connections for bottom-treatment were made in October, the gold-extraction rose at once from 48 per cent in September, to 75 for October; and the average actual gold-recovery for the last quarter of the year was 80.23 per cent, while the actual silver-recovery also rose from 25 to 41 per cent.

The total time of treatment was from 9.5 to 11.5 days. The average rate of percolation was 1 inch per hour, although 64 and 71 per cent gold extraction were obtained from charges having only 0.5-inch and 0.6-inch rates. The highest rate during this period was 1.5 inches per hour. This slow percolation means high cyanide consumption and long treatment; but it also means larger slimes-tonnage treated. It does not require a large increase in daily tonnage to pay for extra vats and a little more cyanide.

Residues are discharged through two 10-inch plug flanges placed 4 feet from the sides of the vats. A 2.5-inch hose with 2-inch nozzle is used under 115 pounds pressure, the hose being held in a swivel-clamp at the edge of the vat. The bottom 6 inches is cleaned out at reduced pressure. One man will sluice out a charge and clean the filter in from 3.5 to 4 hours.

The filter is three thicknesses of 16-ounce burlap, having the usual false bottom and rope-grouting, and anchored to the vat-bottom to counteract its buoyancy.

Precipitation is effected by zinc shavings in eight ten-compartment steel boxes, and it is perfect with the weakest solutions when run at the rate of one ton of solution per twenty-four hours per cubic foot of shavings. The shavings in the wash solution-box are lead-dipped. Whenever there were values in the effluent, running at the normal rate, they were found to be due to precipitate mechanically carried over after dressing boxes, and it was found best not to disturb a box after it had been running more than a week, but to add shavings on top as required.

The clean-up method, while it just about competed with refiners' rates, was not satisfactory. The precipitate was dried, fluxed and smelted direct, without either acid or roasting treatment, and without refining, which produced a bullion of 720 total fineness. The treatment-loss was 1 per cent of the gold and 0.5 per cent of the silver. The clean-up cost, including freight and treatment of the resulting high-grade zinc-slag, was 17 cents per pound of dried slimes. This does not include charges for bullion shipment.

Operating costs per ton in detail for the last quarter, when 7150 tons were treated, were as follows:

Cost of Treatment per Ton

Cyanide, at $0.22 per pound	$0.200
Zinc, at $0.09 per pound	0.020
Lime, at $0.009 per pound	0.001
Fuel, at $2.50 per cord	0.019
Clean-up supplies	0.020
Repairs	0.014
Miscellaneous	0.003
Labor (wages at $3.50 and $4.50 per day)	0.234
Total	$0.520

Assay-office costs were not allocated; but the cyanide-plant proportion should approximate $0.025 per ton. These results were obtained when treating but 78 tons per day. The author states that this cost can be reduced to 38.6 cents when the plant is treating its full-rated capacity of 200 tons per day; and the introduction of reverberatory and cupel furnaces for clean-up would still further reduce it.

PIONEERS OF ELECTROCHEMISTRY.—VII.

Thomas A. Edison.

Thomas Alva Edison was born on February 11, 1847, at Milan, Ohio. His fifty-seventh birthday, and at the same time the twenty-fifth anniversary of the practical perfection and commercial introduction of the incandescent lamp by Edison, was celebrated by a most notable dinner of the American Institute of Electrical Engineers at the Waldorf-Astoria. In one of the speeches Mr. S. Insull expressed the conviction that posterity will not adjudge us of undue enthusiasm if we name Edison as the greatest electrochemical experimenter and the first electric light engineer of his day.

Mr. Edison's life and work is too well known to need recording here. But it seems that in view of the overwhelming results of his gigantic work in electric lighting and in general electrical engineering, it is mostly overlooked that Mr. Edison is one of the strongest and most successful representatives of industrial and applied chemistry and electrochemistry of to-day.

Copyrighted, 1904, by N. Lazarnick.

Thomas A Edison

In developing the incandescent lamp, Mr. Edison was a chemist. The preparation of the filament involved difficulties which were of a distinctly chemical nature. In this connection we may mention that it is surely not incidental that the Nernst lamp, the osmium lamp and the incandescent gas light were invented by distinguished representatives of electrochemistry and chemistry; the recent achievements in arc lighting with impregnated carbons are also due to chemical research. The development of a new illuminant always requires a chemical mind, and Thomas A. Edison did here the most important and most decisive pioneer work.

While electrical engineering quickly grew so enormously that specialization soon followed and electrical engineers became either dynamo designers or lighting engineers or tramway engineers, etc., Mr. Edison always remained broad-minded, never losing sight of the whole. This explains why he was so successful in so many fields.

One of his earliest applications of electrochemistry to electrical engineering was the design of electrochemical meters in various forms for measuring ampere hours; this is, of course, a direct application of Faraday's law to the purpose of general electrical engineering.

For a long series of years Mr. Edison has been interested in the application of electromagnetism for the concentration of ores, *i. e.*, in the design of magnetic separators.

The most intimate connection of Mr. Edison with electrochemistry is, however, in the battery field. The old Edison-Lelande cell is witness of his early interest in the battery problem, and when in recent years with the boom of automobilism the inherent advantages of electric automobiles, and the inherent disadvantages of the lead storage battery for this purpose became obvious, Mr. Edison quickly attacked the problem of designing a light accumulator battery and solved it. A remark which he is quoted to have made is characteristic of him; it is to the effect that if Nature had intended lead to be used for an automobile battery, lead would not have the weight it has.

Mr. Edison, however, not only intended to produce a light battery, but one which is absolutely fool-proof. The mechanical perfection of his battery is denied by nobody, but the immense work he has done to make it chemically perfect, is probably not generally recognized.

His method of research in this special case has been the same as in all his former work to try everything, and keep the best. Mr. Edison knew exactly what he wanted: active materials which may be easily oxidized and reduced by electrolysis, and which, in all states of oxidation, are absolutely insoluble in potassium or sodium hydroxide. Mr. Edison tried the whole series of available metals, and all available methods of preparing the active material. The patents which were taken out by him, and which were duly recorded in our columns, tell only a small portion of his work, but his iron-nickel cell tells his success. The care taken by him to get pure materials is astonishing.

The fact that Mr. Edison has finally succeeded in making the steel containers for his battery in a perfectly satisfactory manner by electrolytic deposition upon a suitable mould, is another pretty example of his experimental skill in electrochemistry. Mr. Edison told the writer the other day that at the start the task seemed almost hopeless, but he kept on trying, since he was convinced that all such problems can be solved by systematic and persevering work. It is a favorite saying of Mr. Edison that inspiration, in the main, is only another way of spelling "perspiration."

Mr. Edison is of a very generous and kind nature and extremely modest; he never made a speech, never read a paper before a society, never published a book on his work. In personal intercourse, however, he is full of life and nerve and wit, and while, in speaking of paper patents, he may get quite sarcastic, his conversation is generally characterized by a very good-natured humor.

What every American engineer, and really every American feels for Mr. Edison, was admirably put into words by Mr. T. C. Martin as toastmaster at the Institute dinner: "Let us and let our sons recall and applaud the cheery little newsboy at Detroit; the half-shod, half-frozen operator seeking bravely a job along the icy pikes of the Central States; the gaunt, untutored experimenter in Boston, taking eagerly needed fees for lectures he was too modest to deliver; the embryonic inventor in New York, grubstaked by a famous Wall Street man for his first stock ticker; the deaf investigator at Menlo Park who wreaked unique retaliation on his affliction by preserving human speech forever with his phonograph; the prolific patentee who kept the pathway to the Patent Office hot with his footsteps for nearly forty years; the genius, our comrade, who took this little crystal bulb in his Promethean hand and with it helped to give to the world a glorious new light which never was before on land or sea—Thomas Alva Edison."

THE POWER PLANT OF THE MOCTEZUMA COPPER COMPANY AT NACOZARI, SONORA, MEXICO.

In nearly all the electrochemical processes, be they electrolytic or electrothermic or a combination of both, the cost of power is a large fraction of the total cost. This is well emphasized by the fact that the bulk of the electrochemical industries of this country settled down where cheap water power was available, at Niagara Falls. The same fact is also indicated by the increasing interest with which electrometallurgists follow at present all new developments in the use of the waste gases from blast furnaces for operating gas engines. Cheap power is indeed in most cases the fundamental supposition of the economical operation.

On the other hand, it is not to be overlooked that cheap power is not everything. The availability of the raw materials at the place of manufacture, and the possibility of easy shipment of the manufactured goods are also important. The question which kind of power to choose, therefore, depends to a large extent on local conditions.

An interesting, and, in several respects, quite novel gas engine-driven electric power plant is that of the Moctezuma Copper Co., at Nacozari, Sonora, Mexico. From a paper of Mr. John Langton, presented before the *American Institute of Mining Engineers*, we gather the following information:

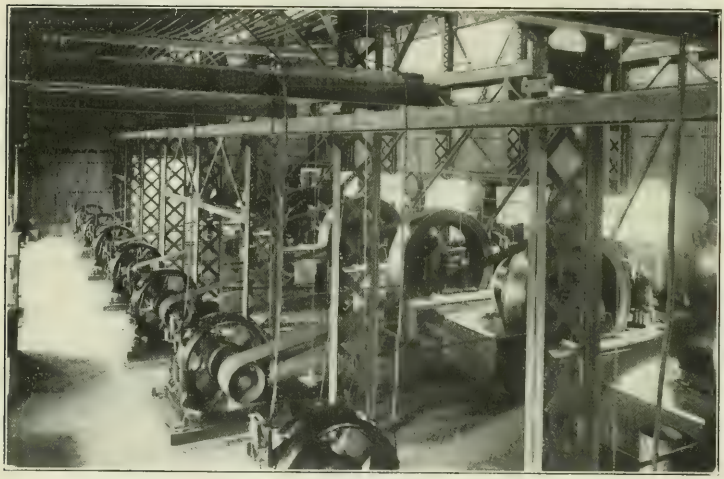


FIG. 1. POWER PLANT OF THE MOCTEZUMA COPPER COMPANY.

The power house, the interior of which is shown in Fig 1, contains eight single cylinder Crossley gas engines, 18.5 inches diameter by 24-inch stroke, running at 200 r. p. m. These engines are of the four-cycle type, with "hit and miss" governor. Each engine is direct-belted to a 65-kw. direct-currrent generator. The generators are run in parallel, and deliver to the main switchboard in the power house, from which the current is distributed at 250 volts to some 40 different motors scattered about the works, ranging in size from 5 hp. to 175 hp. Arc and incandescent lights are operated from the same circuit as the motors.

The engines are started by compressed air, a method which has been found very simple and convenient. The cock opening and shutting off the admission of compressed air to the engine cylinder is worked by hand. Frequently but one impulse with compressed air is needed, and seldom more than three.

The gas producers are those of the Loomis-Pettibone Gas Machinery Co., arranged as shown in Fig. 2. The draught through the producers is created by the suction of the gas-exhauster, and air enters through the open feed-doors in the top of the producers. Through the same doors the fuel is charged by hand. The air thus comes into contact first with the fresh fuel, and the products of combustion, together with any distillates from the fresh fuel, are drawn downwards through the deep charge of incandescent fuel and out through the fire-brick grate at the bottom of the producer. The high temperature of the gas drawn out of the producer is partially utilized to generate steam in the boiler, through which the gas next passes, and from which it emerges cooled to about the ordinary temperature of chimney gases. It is further cooled to about atmospheric temperature in passing through the water-sprayed coke-filled trays of the scrubber, from which it finally reaches the exhauster which delivers it into the holders.

The quantity of gas made is controlled by the speed of the exhauster, which is of the positive type. The vacuum on the suction side of the exhauster, required to produce the necessary draught, depends upon the condition of the fires and the quantity of gas being made, but ordinarily it is from 12 to 24 inches of water. The exhauster delivers against the 6 inches of water pressure to which the gas holders are weighted. The total difference of pressure, therefore, is from 11 to 18 ounces.

The steam raised in the boiler is used intermittently to make water gas. For this purpose the feed-doors E and F are closed, and also the valve B. Steam is then admitted under the grate of producer No. 2, and is dissociated at the temperature of the fire, forming water gas in its passage up through producer No. 2, across the top connecting-pipe to producer No. 1, down through the latter, and out by valve A to to the boiler, the scrubber and the gas-holder. The next time water gas is made the direction is reversed; the valve A is closed, and the gas-run is made up through producer No. 1 and down through No. 2. Or, when the half the run is made up producer No. 1, steam may be shut off while valves A and B are reversed, and the other half of the run made up producer No. 2. The latter plan is generally followed at Nacozari, where the method adopted for making gas requires only short and infrequent runs of water gas.

A gas holder of 15,000 cubic feet capacity receives the gas which is to be used in the engines, and gives the necessary elastic storage between the production in the gas house and the consumption in the power house. A second gas holder of 5000 cubic feet capacity is used to receive, and to keep separate, the water gas made by the intermittent runs. By means of valves X, Y and Z, the gas is delivered to either of the holders, or is allowed to escape into the air through the purge pipe.

The producers have 6 feet 9 inches inside diameter; and when charged with coal to the highest level practicable they hold a fuel-charge 8 feet deep. A generating set consists of two producers and one boiler. At Nacozari there are two generating sets which deliver to a common scrubber and a common exhauster, with space provided for the addition of a second scrubber and a second exhauster if desired in the future. The sets are alternated in use. One is run till the accumulation of ash or clinker begins to limit its capacity; the other set is then fired, and blown to incandescence by a centrifugal exhaust fan. The valve connecting the new set to the scrubber and exhauster is opened, and the valve connecting the old set is closed. There is no interruption to the

process of gas making. By means of the cleaning doors at the grate level, the producers of the old set are then emptied, and cleaned of ash and clinker. The cleaning doors are closed and sealed air-tight, and the producers charged with fuel ready to fire up again when their turn comes. The length of run on one set depends on the rate of gas making and on the percentage of ash in the fuel. At the rate of gas production required for an average load of 600 brake-hp., about 80 tons of the ordinary western coal, or about the same weight of wood, may be gasified before the accumulation of ash and clinker necessitates cleaning.

The water used in the scrubber is caught in a lower tank, and pumped back over a small cooling tower to the head tank supplying the scrubber. The feed-water for the boiler is drawn from the supply already purified by soda treatment for use in the engine jackets.

The plant has been operated with wood and with coal, both anthracite and bituminous. The down-draught principle of the producers, by which all gases pass out through the bottom of the fire, has proved thoroughly efficacious in producing fixed gases from all kinds of fuel used at Nacozari. The water from the scrubber rarely shows even that trace of tar which manifests itself by an iridescent film on the surface of the water in the lower scrubber tank.

A considerable quantity of very finely divided carbon is carried through the scrubber and into the holder and mains. It is unnoticeable at the engine valves, but it gradually deposits in the gas mains, which must occasionally be flushed out. An efficient dry scrubber to prevent its passage would be an improvement.

With fuel delivered in the gas-house bins, the attendance required is one gas maker and one helper on each shift, and extra labor for cleaning the producers.

Method of Making Gas.

In the Loomis-Pettibone producers, as ordinarily used with the object of making as much water gas as possible, the aim is to get the fires very hot before making water gas, and to continue the admission of steam until the fires are cooled to a point where a considerable portion of the steam passes through unaltered; the making of producer-gas with air is then resumed with the aim of quickly blowing the fires as hot as possible, preparatory to steaming them again to make water gas. This procedure necessarily causes great variation in the temperature of the fires, and this, though it has little effect on the quality of the water gas, has a very great effect on the quality of the producer gas, since the latter when made by blowing a cold fire, has a large percentage of CO_2 and is lean in the combustible CO; while with a hot fire, the percentage of CO_2 is very much less, and that of CO more than correspondingly increased—one volume of CO_2 being converted into two volumes of CO.

The original intention was to make producer gas and water gas at Nacozari in the usual manner by alternate blowing and steaming, the two kinds of gas to be delivered into two separate holders, and from these drawn in definite proportions through a mixing-valve into the gas main leading to the engines. But since, in this plant, only one set of producers is available, the quality of the mixed gas would have been too variable. The method of gas making was therefore modified to avoid great variations in the temperature of the fires. The steam-pipe connections, marked M in Fig. 2, permit the introduction of steam together with the air to the top of the fire, and by this means the excess heat of the fire caused by the air-blowing may be concurrently used to make water gas; so that by properly proportioning the quantities of steam and air introduced, the fires may be maintained at a practically uniform temperature for a long period of time. The practice is to admit somewhat less top steam than could be used, in order to allow the fire to increase slowly in temperature; and then, without allowing the temperature to become excessive, to make a short water gas run which only slightly cools the fire, and to resume immediately the making of mixed gas with top steam. By this method the fire is never allowed to become cold enough to make an undue proportion of CO_2, and its maximum and minimum temperatures vary but slightly from an average high temperature.

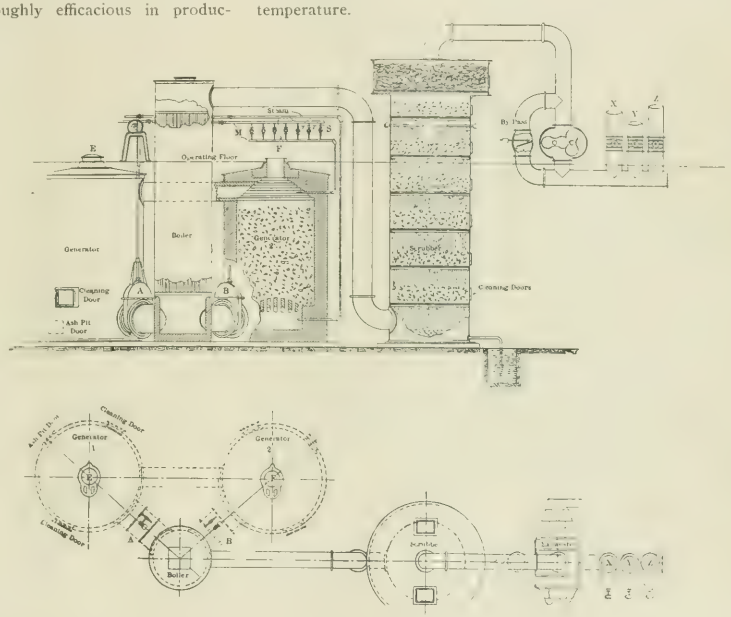


FIG. 2 GAS PRODUCERS, MOCTEZUMA COPPER COMPANY.

The water gas made separately by this method and delivered into the water-gas holder is gradually fed from the latter into the main holder which supplies the gas engines, the water-gas holder being weighted to give an inch or two greater pressure than that of the main holder. The rate of feed is controlled by a throttle-valve, in a pipe connecting the two holders, which the operator manipulates so that the rate of feeding water gas approximately equals the rate of its production. No particular accuracy is required, nor are pains taken to regulate the quantity of water gas made separately. The operator is governed principally by the temperature of the fire, as indicated by its appearance and by the rise of steam pressure in the boiler.

The regulating cocks, marked S in Fig. 2, are drilled with small holes, and the quantity of the top steam is regulated by the number of cocks open. This gives a graduated regulation and the ability to duplicate conditions exactly. The quantity of air is independently controlled by the speed of the exhauster, or by slightly opening, to a graduated extent, the by-pass valve of the exhauster.

Gas Made From Wood.

The most novel feature of the Nacozari power plant is the use of producer gas made from wood alone, which is comparatively inexpensive in the neighborhood. The most obvious difficulty to be feared arose from the large proportion of condensible distillates yielded by wood, and the danger that some portion of these might be imperfectly fixed in passing through the producer. The trouble from tar deposited in the gas apparatus and pipes would be serious, and even a small quantity of tar in the gas itself is a fertile source of trouble at the engine valves. Unless a permanent gas could be made from wood, this fuel would be unavailable.

The first care, therefore, was to insure that there should be a bed of charcoal on the grate sufficient to form an adequate fixing zone. Although in a first trial charcoal in sufficient quantity proved effective in fixing all of the gases, it was felt, rightly or wrongly, that coke would be a stouter and more reliable screen than the comparatively frail charcoal; and in particular, that, as a reinforcement to the charcoal formed above it by the action of the fire, it would effectually safeguard against the possible danger that temporary holes might be burned through the charcoal, by which tar vapors might escape from the producer, but for the fixing-action of the more enduring coke. However correct this opinion might be, a coke-bed would certainly be an additional precaution against the serious trouble which might result from delivering imperfectly fixed gases to the holder, and would give to the operator great relief from anxiety on this score. It was therefore thought best without further experiment to use coke, which was available at Nacozari; and the practice has been continued ever since. The experience at Nacozari, therefore, does not determine whether it would be safe to dispense with the use of coke.

The wood used is principally scrub white oak, with about 10 per cent ash. The quantity of moisture contained in it varies between about 10 and 25 per cent, and is in the average 20 per cent.

Quality of Gas Produced.

The composition of producer gas made from bituminous coal is practically the same as that made from anthracite coal, but differs radically from gas made from wood; the calorific power of all three gases, however, remains constant. The type composition of coal gas and wood gas is given as follows:

Components.	Coal-Gas.	Wood-Gas.
	Volume Per Cent.	Volume Per Cent.
CO	20.0	14.0
H	14.0	20.0
CH_4	2.0	2.0
$C_n H_{2n}$	0.2	0.2
CO_2	8.2	16.0
O	0.1	0.1
N	55.5	47.7
Total	100.0	100.0
Calorific value per cu. ft., calcul't'd at sea level and at 60 F	B. T. U. 132.	B. T. U. 132.

As compared with coal gas, the proportions of CO and H in wood gas are reversed, and the percentage of CO_2 is doubled. With the typical compositions given above the wood gas shows less tendency than the coal gas to pre-ignition in the engines. This effect appears to be due to the large proportion of CO_2, but the reason why this is so is not apparent. Other experience at Nacozari has certainly shown a very marked tendency to pre-ignition in the engines when the gas was approximately of the following composition by volume per cent:

CO, 14; H, 20; CH_4, 2; CnH_{2n}, 0.2; CO_2, 8.2; O, 0.1; and N, 55.5; total, 100.

The calorific value of this gas was 132 B. T. U., and yet it had the same ratio of incombustibles to combustibles, and the same composition of the latter, as the cool-working wood gas. The only difference is in the composition of the incombustibles; and it is very obscure why a change in the relative proportions of CO_2 and N should produce such markedly different results in the behavior of the engines.

The Use of Gas Engines.

Mr. Langton's paper is concluded by some interesting general remarks on the use of gas engines. The sustained capacity and satisfactory working of a gas engine depend on its being kept in thoroughly good condition. The principal meaning of "good condition" is, that the valves should seat freely, and be tight when seated; and that the inside of the cylinder should not be foul with carbonized oil.

The rated capacity of a steam engine being approximately at that point of cut-off where it uses steam most economically, there is always available a considerable reserve capacity, at the expense of economy, by admitting steam for nearly full stroke. The most economical capacity of a gas engine is its absolute maximum capacity, when at every admission it takes the maximum quantity of mixture, in the best proportions of air and gas, and ignites it at exactly the right point. The adjustments necessary to obtain all these conditions with certainty at every stroke, are too fine for any but test conditions. To allow for variations, which are inevitable, even under the best conditions in commercial working, the maximum capacity should be discounted about 15 per cent to get a figure which may be called "maximum commercial capacity;" and nothing more than this latter figure should be counted upon for those short periods which occur, even with the most uniform load, when the load rises to a maximum greater than the average. In other words, this commercial maximum capacity should equal the peak of the load curve. With a very variable load, therefore, an engine-capacity is required greatly in excess of the average power demand; and any method of averaging the power variations of individual loads by driving several such loads from one group of engines will reduce the total engine-capacity to be installed. The central power house plan with electrical distribution, is, therefore, one which is well worthy of careful consideration for at least some portion of any gas-power plant, in spite of the heavy tax to be paid in transformation and transmission losses, losses in the electric generator, the line and the motor, which practically amount to 25 per cent of the brake horse power delivered by the engines.

The ease with which gas may be transmitted to scattered points without loss, and the heavy power loss involved in transforming and transmitting the power by electric distribution, at first sight makes it appear as though the advantages of using scattered gas engines, directly connected to the shafting, would far outweigh any benefits obtainable by electric distribution from gas engines concentrated in a power house. But when the peculiarities of the engines themselves are considered, in many, not to say most cases, the balance of advantage is found to be on the side of electrical distribution, notwithstanding the cost of electrical apparatus and the constant electrical loss of 25 per cent of the power delivered by the engines.

Manganese Industry in the Caucasus.—Government statistics relating to the manganese industry in the Caucasus during 1901 have just been published as noticed in a recent consular report. In regard to the production of manganese, the first place belongs to Russia, which yields more than half the world's product. Layers of manganese exist in the Perm, Orenburg, Ekaterinoslav, and Kutais (Caucasus) Provinces. The latter are the richest, occupying an area of 54.7 square miles. The amount of manganese exported in 1901 was 355,545 metric tons, against 461,125 tons in 1900. The chief importers were: Great Britain and Holland, consuming 36 per cent and 29 per cent, respectively, of the total amount exported; next came the United States, with 14 per cent; Belgium, with 4.5 per cent; Germany, with 4 per cent; and France, with 2.5 per cent. Russia consumed only 8.5 per cent of its total yield.

NOTES ON THE LIMITATIONS OF THE CYANIDE PROCESS*

By H. T. Durant.

Speaking very generally it may be stated that it has almost become an axiom that the surface equipment of a gold or gold-silver mine is not complete without a cyanide plant.

This is no doubt, in part, due to the success attending the Witwatersrand plants, and these have been extensively copied in various places, where sometimes at least local conditions and the varying natures of the ores hardly permit such, or any, cyanide plants to be profitable.

It may be very broadly stated that ores which are amenable to any method of cyanide treatment fall naturally into two classes:

(1) Those in which the gold is carried mainly in the mineralized portion of the ore.

(2) Those in which the gold is carried free in quartz or other gangue.

The first class includes all ores in which payable values are carried in iron, copper or arsenical pyrites, tellurides, etc., or the oxidization products of one or more of these minerals, and this class permits of a wide range of treatment, varying according to special circumstances. There may also be ores intermediate between these two classes, such as the Witwatersrand ores. It is, however, principally with ores of the second class that the few remarks in these notes deal.

There are, in Rhodesia, several properties in which the ore is a fairly clean quartz, very slightly mineralized, the mineralized portion being poor in values and representing considerably less than 1 per cent by weight of the ore.

Such ores, when milled, yield values to the plates which are proportional to the fineness of the product from the mill.

If the gold in the ore is fairly coarse, the values in the mill tailings are usually such that, after milling with, say, a 700 screen apparently the mill tailings might at first sight be neglected as regards further treatment, at least on small propositions.

On the other hand, if the gold is very fine, even by increasing the battery screen up to even 1600, the tailings will still be found to be a valuable asset.

But whatever values may be in the tailings, it is found that the values extracted by cyanide are such as would in all cases entail an unsatisfactory residue, and in most cases would mean that the cyanide plant would be run at a very small profit, and this would be especially the case on small properties, where the working expenses per ton would naturally be relatively high.

There is fairly conclusive evidence that the unsatisfactory extractions by cyanide mentioned above are due to the fact that the major portion of the gold passing the plates is locked up in the gangue, and therefore not accessible to cyanide solutions, or conversely that when the ore is crushed fine enough to expose or free the gold that very nearly all the values are caught on the plates; in other words such ores are free milling propositions in the fullest sense of the term.

Table I. shows the results of actual work at the mill of the Guinea Fowl mine; these results were obtained, for confirmatory purposes, soon after the starting of the mill, practically identical results having been obtained experimentally before the starting of the mill.

The tailings under consideration in Table I., when assayed as a whole, were found to carry 4 dwts. of fine gold per ton (short).

It is seen that while slightly over 4 dwts. of fine gold are in each ton of tailings that 3.195 dwts., or nearly 80 per cent of the total values, are carried in less than 35 per cent of the total tonnage.

In other words, it is in this case merely necessary to take out by any simple sizing arrangement that portion of the tailings which fails to pass a 6,400 square measure screen, and one will then have obtained from each 100 tons of 4-dwt. tailings 34.5 tons of tailings, going 9.2 dwts. fine gold per ton, leaving 65.5 tons of tailings carrying 1.5 dwts. gold per ton, and these are more or less valueless according to local conditions.

Table I.

Wet Classification of Tailings from Guinea Fowl Mill.

Size of material	Percentage.	Assay value dwts. fine gold per ton.	Representing dwts. fine gold per ton of tailings.
Staying on 3,600 screen (square measure)	22.5	11.00	2.475
Passing 3,600 screen (square measure), staying on 6,400 screen (square measure)	12.0	6.00	.720
Passing 6,400 screen (square measure)	65.5	1.50	.982
Assay value of tailings by calculation from constituents			4.177 dwts.

Table II. shows wet classification of tailings from another mill. The tailings, though very low in value, still well illustrate the values of the various sizes in the mill product:

Table II.

Size and description of material.	Percentage.	Assay value dwts fine gold per ton.	Representing dwts. fine gold per ton of tailings.
Finer concentrates panned from portion of tailings passing 2,500 screen (square measure)	4.13	4.00	.165
Coarse sand (including coarser concentrates) staying on 2,500 screen (square measure)	25.90	2.80	.725
Fine sands and slimes passing 2,500 screen (square measure)	69.80	.85	.594
Experimental error	.17		
Assay value of tailings by calculation from constituents			1.484 dwts.

Notes on Table II.—These tailings, assaying practically 1.50 dwts. fine gold per ton, are seen to carry .89 dwts. or 60 per cent of their total values in 30 per cent of their total tonnage; that is to say, that every 100 tons of 1.5 dwts. tailings will yield 30 tons tailings, assaying slightly less than 3 dwts. per ton.

It has been stated before that the total tailings mentioned either in Table I. or Table II., or any of the constituents of either tailings, yield unsatisfactory extraction by cyanide, similarly it has been proved that any of the constituents on crushing finer, yield to plate amalgamation, and also to cyanide solutions, gold in proportion to the fineness of the crushing.

In the case of tailings mentioned in Table II. it is clear that it would be good procedure to mill with a coarser screen, so that, while increasing the stamp duty, the oversize taken out from the tailings for recrushing and further amalgamation should be of a higher gold value.

The writer is acquainted with at least one case in which fine crushing of the whole ore followed by amalgamation yields exactly the same results, as regards recovery of gold, as coarser crushing with amalgamation followed by cyanide plant for the sands; in such case it is merely a question of capital expenditure and total working costs to determine which method to adopt; on the other hand, in the case of ores mentioned in

* A paper presented to the Chemical, Metallurgical and Mining Society of South Africa.

preceding tables there could be no question of cyanide plant unless after fine crushing it were cheaper to treat by cyanide than to run over plates.

Instances of this kind could, if necessary, be multiplied. It would appear that when an ore, after crushing and amalgamation yields slimes which do not pay to treat, it is good practice to increase the percentage of these slimes as much as possible while still keeping the value of the slimes below the paying point; such procedure is corelated to the well-known milling practice of California and Gilpin County.

Without intending to discuss in these few notes the question of milling in its most modern aspects, it may be taken for granted, that any exceptionally fine crushing would not usually be carried out in a stamp battery.

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By George P. Scholl, Ph. D.

Electric Furnaces and Furnace Products.

Method of Making Carbon Articles.—E. G. Acheson, Niagara Falls. Patent 749,418, January 12, 1904. Application filed September 4, 1902.

Mr. Acheson discloses a process for making carbon articles of a high density and conductivity, by heating them up in an electric furnace, without reaching the point of graphitization. Articles thus heated increase in density from 2 to 2.13, while their conductivity is increased from 100 to 200 per cent, and the loss, which they suffer when used as anodes in an electrolytic bath, is considerably reduced. The articles are embedded in a resistance material, the specified resistance of which is greater than that of the articles. It is not intended to produce heat in the carbon articles as a result of the passage of the current through them, but to heat up the resistance material, the heat of which is then transmitted to the carbon articles which are placed in the furnace in a direction approximately at right angles to its longest dimension. A furnace which has been successfully used for this purpose is approximately 30 feet long, 30 inches wide, and 10 inches deep, inside measurements. It is constructed of ordinary bricks, but in some cases it is provided with a refractory lining of carbide of silicon. The resistance material is granular carbon, a mixture of granular carbon and silica or other metallic oxide, metallic powder or any other material conforming to the conditions stated above. A layer of the resistance material is placed on the bottom of the furnace and then the carbon articles are arranged on it, with their longest dimensions at approximately right angles to a line joining the furnace terminals. The space left between the articles is varied with the dimensions of the articles to be treated, good results being obtained with a space representing 20 per cent of the width of the carbon articles. The space between the articles is then filled with the resistance material, and layer after layer built up in the same manner. After the furnace has been filled, the top is covered with a layer of refractory and high resistance material for the purpose of excluding the air. If the articles to be treated have received already a previous baking, and are therefore conductors, they are superimposed upon each other directly, without any intervening horizontal layers of resistance material. In a furnace of the dimensions given above, good results have been obtained with 200 volts and 3750 amperes at the beginning, the volts gradually decreasing and the amperage increasing, until, at the close of the operation, after fifteen hours run, the e. m. f. was 87 volts, with a current of 8580 amperes.

Process of Electrically Heating Materials.—Alfred H. Cowles, Cleveland, Ohio. Patent 750,095, January 19, 1904. Application filed November 5, 1902.

The process consists in the use as a heating means of a resistance conductor placed in proximity to the materials to be heated, the current density being increased and the temperature thus raised continuously along the path which the material travels. The process is specifically intended for the manufacture of calcium carbide. A form of apparatus in which it may be carried out is illustrated in Fig. 1. The apparatus comprises an inverted conical stack, having an iron shell 3, a lining of refractory material 4 and a water jacket 5. The hearth is of carbon, inclosed in a casing 6, which is connected with one terminal of a source of current. A tapping hole 7 is also provided. The top is closed by a plate 8 of carbon surrounded by a casing 9. Below the massive carbon is arranged a carbon ring 21, surrounded by a water jacket 22. The cover forms the other electrode of the apparatus, and is insulated from the upper end of the stack by a ring 20 of asbestos. A central hopper 10 is provided in the cover, and a series of hoppers 11 are situated around the edge. Broken, loose or granular refractory conducting material 14, such as lumps of coke or carbon, is fed through hoppers 11, while the central hopper serves for the introduction of the charges. The material 14, arranging itself in a vertical layer around the column of charge 15, decreases in cross-sectional area towards the hearth, and the heat generated in it by the passage of the current increases gradually. The carbide formed after the material has reached the zone of reaction may be tapped intermittently, or allowed to run out continuously, fresh material being fed through hopper 10, as the column of charge descends, while the material of the conductor is replenished through hoppers 11.

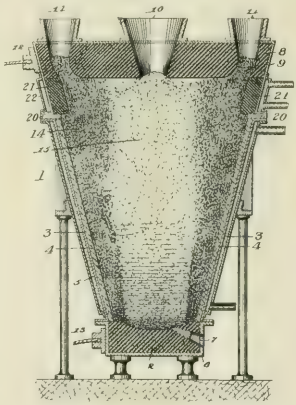


FIG. 1.—COWLES FURNACE.

Electric Resistance Furnace.—Alfred H. Cowles, Cleveland, Ohio. Patent 750,093, January 19, 1904. Original application filed November 20, 1902. Divided April 21, 1903.

The specification illustrates several forms of apparatus suitable for carrying out the process described above. The first form is identical with that shown in Fig. 1. The second form is a horizontal furnace, the end walls, floor and roof of which are of refractory material. The hearth is a resistance conductor, either composed of loose material or of solid carbon. The upper surface of the conductor slopes towards the tapping hole, and one terminal of the source of current is connected to the conductor at the charging end, and the other at the dis-

charging end of the furnace. A current passing through the conductor thus heats it up more and more towards the discharging end, on account of the gradual decrease in cross-section and consequent increase of current density. A third form of furnace is shown, consisting of an inverted conical shaft, through the middle of which passes a resistance conductor with gradually decreasing cross-section, resting on a carbon hearth, which is connected to one terminal of the current, while the top of the resistance conductor is connected to the other terminal. The charge fills the annular space between the central conductor and the furnace wall. A fourth form of furnace shows a horizontal resistance conductor, constituted by a plate of solid carbon, which narrows down in width from the charging towards the discharging end of the furnace.

Process of Smelting Materials and Producing Carbides.—Alfred H. Cowles, Cleveland, Ohio. Patent 750,094, January 19, 1904. Application filed October 20, 1903.

In this process, which relates especially to the production of calcium carbide, the charge is preheated by passing hot gases through it, and then subjected to the action of the electric current, which is either passed through the heated charge, or its molten products, or through a separate resistance conductor. The current density is increased towards the point where the molten material is tapped out. Two types of furnaces for carrying out the process are shown in the specification. The first form shows an inverted conical shape of the lower part of the furnace, an iron shell lined with refractory material and water-jacketed all around. The bottom, as in the types described above, is formed of carbon and connected with one pole of the source of current. Near the top of the lower part there are introduced a number of cylindrical carbon electrodes, projecting to some extent into the furnace, and connected to the other pole. A preheating chamber of iron lined with refractory material such as siloxicon or magnesite, is supported upon and opens into the upper end of the furnace. The top of the chamber is provided with a bell and hopper. Pipes lead from the top of the furnace chamber proper into the preheating chamber, for the purpose of drawing off the combustible gases and burning them in order to preheat the charge. One or more auxiliary burners, supplied with fuel from other sources, may also be employed. An outlet pipe is provided at the top of the preheating chamber to draw off the products of combustion. The second form of furnace shows substantially the same form of preheating chamber, but the electric furnace proper is constructed horizontally with the carbon conductor forming the bottom and sloping, as in one of the types mentioned above.

Process of Effecting Chemical Changes.—Alfred H. Cowles, Cleveland, Ohio. Patent 750,096, January 19, 1904. Application filed November 5, 1902.

The process relates specially to the production of carbides, such as calcium carbide, and consists in passing an electric current through a body of carbide-forming materials, acting as a resistance conductor, and increasing the current density along the path of the current to a point where the heat generated by the resistance of the body causes the materials to react to form carbide. The type of furnace shown in connection with this process consists again of an inverted conical shaft of iron, water-jacketed and lined with refractory material. The iron shell is, however, separated into two parts, insulated from each other by a ring of asbestos. The upper part is provided with a ring of carbon, replacing the upper part of the lining and connected to one terminal of the currents. The hearth, composed of carbon, serves as the other electrode. It is not essential that the charge should consist of a mixture which is a conductor at ordinary temperatures, and the process may also be employed for the production of calcium carbide from a mixture of ground coke and lime. It is necessary in that case to provide an initial conducting path or high-voltage to start the operation.

Method of Electric Heating.—Alfred H. Cowles, Cleveland, Ohio. Patent 750,170, January 19, 1904. Application filed November 5, 1902.

The object is to provide a method wherein a body of conductive material in a molten state is interposed between electrodes to establish a path for the current, and a gradation in the current density obtained at the same time, the method being particularly applicable to the formation of calcium carbide. The furnace for carrying out the process has a circular body and hearth of refractory material, a carbon electrode extending through the bottom and serving as one terminal of the current. The body of the furnace is encased in a water-jacketed iron shell. An iron cover, with double walls, between which water is circulated, covers the top of the furnace, and the lower part of the cover is lined with carbon. The cover is connected to the other pole. A tapping hole is provided as usual. The current employed is stated to be of sufficient voltage to maintain within the furnace a body of molten or partially molten carbide, and partly reduced material, sufficient to nearly, or quite, fill the hearth.

Electric Furnace.—Alfred H. Cowles, Cleveland, Ohio. Patent 750,171, January 19, 1904. Application filed November 20, 1902.

The furnaces described in this specification are identical with those mentioned under the heading of the preceding process patents.

Process of Separating Metals from Matte or Ore. Paul Dankwardt, Deadwood, S. D. Patent 746,797, December 15, 1903. Application filed June 20, 1903.

The invention relates to a process for the smelting of matte or ores of similar composition, such as sulphide or sulpharsenide ores, in an electric furnace, with exclusion of air, the matte or ores having been previously mixed with a carbide or with carbide-forming materials. The operation is carried out in a furnace with a fireproof base, which supports water-jackets. The bottom slopes towards the tapping hole, and two electrodes of carbon are introduced into the furnace from opposite sides. The top of the furnace is provided with a hood of brick or metal, an outlet-flue for gases and charging openings with doors. The furnace is charged with a mixture of matte or iron sulphide or arsenide ore, which carries gold, silver, copper, lead or nickel, and a carbide or carbide-forming ingredients. If limestone and carbon are used, 0.473 parts of limestone and 0.066 parts of coke are used for each ton of ore. The proportion of the matte or ore and the carbide or carbide-forming materials, is stated to be such that the carbide will be just sufficient to reduce all the sulphides or arsenides of the valuable metals which are to be separated, but will not be sufficient for the reduction of the sulphide of iron. The reaction is stated as follows:

$$2CaCO_3 + 2C + CuS + PbS + FeS = Cu + Pb + 2CaS + FeS + 2CO + 2CO_2,$$

in the case of a copper-lead-iron matte carrying gold and silver. It is stated that while the process is going on, there will run out of the furnace a metal or an alloy carrying the gold and silver of the matte or ore, and a changed iron matte and calcium sulphide or arsenide with some slag formed by the impurities of the charge. If, instead of the lime and carbon, a mixture of oxide or carbonate of iron and carbon be used, the sulphur or arsenic, etc., will be taken up by the iron of the carbide of iron formed in the reaction, and an increased quantity of sulphide of iron will run out of the furnace.

Process of Recovering Zinc from Sulphide Ores. P. Dankwardt, Deadwood, S. D. Patent 746,798, December 15, 1903. Application filed August 15, 1903.

The inventor states that the process is particularly adapted to the treatment of ores which carry lead-zinc sulphide copper-zinc sulphide, concentrates from these classes of ores, which are too low in value for direct treatment, and furnace products

such as flue-dust, matte, etc. The process is carried out in an electric furnace, which consists of a foundation of refractory material, on which rest the walls of a retort. The latter is cooled by water-jackets. The rear end of the retort opens just level with the bottom of a vertical shaft, which is provided with a cover. A carbon block is introduced through a perforation in the side of the retort, and another carbon block enters through an opening in the arched top of the retort. A charge-opening and a tapping hole are also provided, and a pipe leads from the retort to a receptacle with a small outlet pipe for gases. The ore is dried and mixed with fluxes and such amounts of an alkali salt or a carbide or carbide-forming materials, that all the sulphur combined with the zinc, lead or copper of the ore will find sufficient alkali metal to combine with when the charge is heated. The mixture is introduced through the shaft and is covered by coke introduced through the opening in the top of the retort, after which current is put on the furnace. If iron pyrites are present, the ore should be mixed with such proportions of alkali salt and carbide-forming materials, that enough of the sulphur of the iron pyrites is withdrawn, so as to cause the latter to be transformed into an iron matter. The inventor illustrates the process by describing the reactions in the case of an ore composed of

$$ZnS + PbS + CuS + FeS_2 + SiO_2 + FeO.$$

This is mixed with sodium sulphate, lime and coke. The reaction is stated to proceed, probably in such manner, that the sodium sulphate is first reduced to sulphide, with evolution of carbon monoxide. As the temperature rises to the point of formation of carbide, the latter reacts with the sodium sulphide, forming calcium sulphide and metallic sodium, which latter in statu nascendi attacks the heavy metal sulphides, and reforms sodium sulphide, setting free the heavy metals. The silica and the protoxide of iron are fluxed off by the addition of limestone. As carbide-forming materials, the inventor prefers to use limestone or iron ore and coke or coal, but alumina or magnesia may also be used. The alkali salt is preferably sodium sulphate. The mass is said to melt under the influence of the heat of the current, the zinc going off in the state of vapor and condensing in the receptacle m, while the other metals will run down the inclined bottom of the furnace. They are tapped out at the tapping hole, together with the sulphides of sodium and calcium, the iron matte and the slag. The metals and the matte are allowed to settle out, and the sulphides and the slag are broke up after cooling, and the sodium sulphide leached out with water. It is proposed to treat this solution with a current of CO_2, thus converting the sodium sulphide into carbonate and driving off the H_2S. The latter is to be turned either into sulphur or sulphuric acid.

Electric Furnace.—Le Roy W. Stevens and B. Timmermann, Chicago, Ill. Patent 749,460, January 12, 1904. Application filed August 8, 1902. Renewed May 26, 1903.

The furnace is designed for obtaining metals from their ores, and for the manufacture of borides, silicides, carbides, etc. The construction shows a vertical cylindrical shaft or flue, the lower end of which is inclined and, gradually narrowing down in cross-section, opens into an electric furnace. The latter is of well-known construction, with a sloping carbon bottom forming one electrode, while one or more vertical carbons depend from the top and constitute the other electrode. A tapping hole is provided at the lowest point of the sloping bottom. A flue leads from the upper part of the electric furnace chamber to a point near the top of the vertical chamber. Oil burners are also arranged near the top of the latter. A hopper and screw conveyor feeds the charge into the furnace. At the lower end of the vertical flue a pipe is provided, through which the gases are drawn off by means of a fan or similar apparatus. The gases generated in the electric furnace thus are drawn through the pipe connecting the furnace with the vertical shaft, and travelling downward pass out through the lower pipe. The flame of the oil burners is similarly deflected downward. This construction is intended to effect a thorough preheating of the charge before it is delivered into the electric furnace. Several modifications of the apparatus are described and illustrated in the specification, in which the electric furnace chamber is mounted on trucks and so arranged that it can be detached and removed for repairs.

Electric Furnace.—Le Roy W. Stevens and B. Timmermann, Chicago, Ill. Patent 749,461, January 12, 1904. Application filed October 29, 1902. Renewed June 17, 1903.

This furnace is an improvement on the one described in the preceding specification, inasmuch as the inventors show means for preventing the gases generated in the electric furnace part from being drawn out directly through the lower pipe, instead of passing into the pipe leading to the top of the vertical chamber, and then traveling down the latter to the outlet pipe. These means consist in the arrangement of a pushing device, situated where the vertical flue discharges into the electric furnace, which operates in such a manner that there is always a certain portion of the charge allowed to accumulate in the lower part of the vertical chamber, below the mouth of the outlet pipe, thus sealing the lower part of the vertical chamber and forcing the gases to travel in the prescribed path.

Furnace.—Le Roy Stevens and B. Timmermann, Chicago, Ill. Patent 749,462, January 12, 1904. Application filed October 30, 1902.

This furnace is constructed on similar lines as the two preceding ones, with this difference, however, that there is only one vertical preheating chamber provided for feeding four electric furnaces, one situated on each side. A portion of the charge is allowed to accumulate in the lower part to act as a seal for the gases as described above, and provision is made to apply additional heat to this part in order to keep the material contained in it hot. The construction of the electric furnace part and the vertical chamber in other respects is substantially the same. A safety-valve is provided at the top of the vertical chamber in order to guard against an excess of gas being supplied to the latter.

Electrometallurgy of Iron and Steel.—H. Harmet, St. Etienne, France. Patent No. 750,361, January 26, 1904. Application filed September 30, 1901.

The apparatus in which this process for the reduction of ores is carried out looks much like the ordinary blast furnace, and is provided, like the latter, with bell and hopper. The ores mixed with an excess of coke are fed in as usual, but instead of there being one down-comer for the gas, there are two, a fan is placed in one of them, and the inventor purposes to suck a portion of the gases off and blow them through water-cooled tuyeres into the furnace again right into the zone of fusion. The construction of these tuyeres is rather peculiar. Insulating supports of porcelain are situated inside of the tuyere casing, serving to carry the electrodes. It is thus seen that the electrodes are situated right in the tuyeres and no means whatever is shown whereby they can be adjusted. Moreover, the electrodes have a longitudinal hole through their center, and the supports are pierced to permit the entrance of the gases delivered to the tuyeres into the fusion zone. The gas entering the fusion zone under pressure is forced upwards into the charge, thus transmitting to the latter the excess heat of the fusion zone.

Electric Furnace.—R. C. Contardo, Sèvres, France. Patent 750,753, January 26, 1904. Application filed August 24, 1900.

The inventor claims an electric arc furnace, comprising a hearth having an inclined surface, electrodes above the same, an arch above the hearth, consisting of two symmetrically and downwardly inclined surfaces and side walls parallel to said arch, forming inclined flues. The ores to be treated are introduced through bell and hopper at the top of the furnace, and

descend into the hearth by means of sloping plates, which form the roof of the melting chamber. The whole weight of the ore charge rests on these sloping surfaces, and yet the inventor claims that those plates are thin and good conductors, made preferably of plumbago. This sample will suffice to show the practicability of the inventor's proposition; the specification abounds in similar ones.

Reduction of Metals and Alloys.—F. J. Tone, Niagara Falls. Patent 754,122, November 24, 1903. Application filed January 22, 1902.

The invention applies to the reduction of metals, such as silicon and aluminium, the temperatures of reduction and volatilizati of which are nearly the same. The difficulties encountered formerly in regard to the volatilization of the metal and its union with the uncombined carbon of the mixture to form carbides are stated to be avoided by proper conditions of temperature, proper distribution of heat, and proper arrangement of the charge to be treated in the furnace. The operation is preferably carried out in an incandescent furnace, shown in cross-section in Fig. 2. The walls 2 are constructed of refractory brick, and the floor 3 is composed of a thin layer of refractory brick or tile. Spaces 4 are provided in the bottom for the purpose of allowing the reduced metal to fall through and collect in receptacles 6, arranged in a substructure of brick piers 5, on which the flooring tiles are supported. Carbon blocks 7, 8 are introduced into the furnace near the bottom and the top, and are connected in the middle of the furnace by a vertical column 9 of carbon blocks preferably piled together with intervening spaces. The current in passing through the resistance column from one terminal to the other heats the mixture with which the furnace is filled, evenly and gradually, allowing the reduced metal to collect in globules and sink to the cooler portions of the furnace, and into the receptacle 6. Another type of furnace is illustrated in the specification in which the electrodes are introduced in the same horizontal plane at the ends of a horizontal furnace. The resistance arrangement consists of two or more vertical columns, constructed as described above, set on the floor of the furnace and connected in series by carbon bars disposed alternately at the upper and the lower ends of the columns. Spaces in the floor of the furnace for the metal to pass through and receptacles underneath are provided. The incandescent type of furnace was chosen in order to obtain a wide zone of reaction and a slowly developed temperature, high enough for the reduction of the metal, but not so high, when the latter is immediately removed, as to cause its waste by volatilization and conversion into carbide.

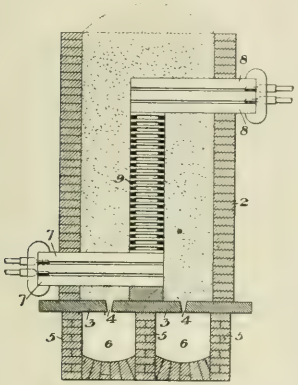


FIG. 2.—SILICON FURNACE.

Process of Electrically Heating Articles.—E. F. Price, Niagara Falls, assignor to Union Carbide Co. Patent 752,357, February 16, 1904. Application filed November 5, 1902.

The process is primarily intended for baking the carbon bars which are used as electrodes in carbide and other furnaces. The furnace used for heating the articles is a rectangular fire-brick structure, the carbon block electrodes being introduced into the end walls. The inner ends of the electrodes project slightly into the furnace and may be protected by a molded carbon block or facing. The articles to be treated are placed in the furnace, separated from each other and surrounded by a filling of material, which is normally a poor conductor, but will become a good conductor when heated. Finely powdered anthracite has been found suitable for this purpose. A central resistance core connects the two electrodes, and the whole is so arranged that the current will in the first instance pass entirely through the core, but will gradually shunt through the packing material as it is converted into a better conductor by the heat generated in the core. The articles to be heated are placed end to end, and a portion of the current may also pass through them and assist in the heating.

Process of Heating Articles by Electricity.—E. F. Price, Niagara Falls, assignor to Union Carbide Co. Patent 752,358, February 16, 1904. Application filed November 5, 1902.

The process differs from the preceding, in so far as the current is passed through the resistance conductor and the articles to be heated, the preferred mode of operation being to pass the current first through the core and then through the articles. The furnace, a rectangular fire brick structure as above, contains a group of electrodes, situated in each end wall and arranged concentrically. They are constructed of a central carbon disc, surrounded by a layer of refractory insulating material, which, in its turn, is surrounded by a ring of carbon, serving as the second electrode. A layer of insulating material separates this again from a second carbon ring, serving as the third electrode, each of the electrodes having terminals for the introduction of the current. The central carbon disc is in contact with a core of broken coke. The articles to be heated, *e. g.* rectangular carbon bars, are placed in concentric layers around the core, the ends of each row of bars being in contact with the corresponding electrode rings at each end of the furnace. The heating is preferably effected by first passing the whole or the major portion of the current through the central core, until the latter becomes heated to incandescence. The switches are then shifted to divert the whole or a considerable part of the current from the core to the first ring electrodes, and the articles lying between them. As soon as they are heated to the desired temperature, the whole or the major portion of the current is diverted to the second ring electrodes and the articles lying between them.

Apparatus and Processes for the Electrolytic Production of Metals and Compounds.

Apparatus for Electrolytic Decomposition of Alkali Chlorides. J. J. Rink, Elsinore, Denmark. Patent 748,985, January 5, 1904. Application filed April 4, 1902.

The apparatus represented in Fig. 3, in longitudinal cross-section, belongs to the type of mercury cells, and is divided into

FIG. 3.—MERCURY CATHODE CELL.

a series of anode and cathode chambers. Salt solution is admitted into the anode compartments *a*, which are open at the bottom and at one side, and rest on lugs so as to raise them somewhat above the bottom of the containing vessel A. The open side of each anode compartment communicates with a passage or compartment running along one of the long sides of the containing vessel. This passage serves for the introduction of the brine and the drawing off of the chlorine. The anode chambers are stated to be constructed of any suitable "conductive" material, which is not liable to be affected by the solutions or gases generated during electrolysis. It would be

very interesting to know what such conducting material is like, but that information is not given by the inventor. The containing vessel A is stated to be made of similar material. A number of carbon rods are arranged in the anode chambers, and are introduced through the top and insulated from the cell material by suitable washers. The width of the anode chambers is given as being from three to five centimeters, ten centimeters at the maximum. The discharge compartments *g* are situated between the anode chambers and their width is about twice that of the latter. The mercury travels through one cell after the other in the direction of the arrow, and at the end of the apparatus is raised by means of a screw wheel *s* into a tank *t* which delivers into a trough *x*, through which it returns to the other side of the apparatus and re-enters into circulation. A solution of water or weak alkali is placed, as usual, into the discharge compartments *g*. The bottom *z* of the containing vessel is provided with raised portions *c* within the decomposing cells, in order to get as thin a sheet of flowing mercury as possible. No data as to current density at anode and cathode are given. The apparatus with its large number of more or less delicate parts, involving, as it does, the necessity of keeping long joints tight, seems needlessly complicated. The uniform movement of mercury over a large surface is not an easy proposition on a large scale in practice. It is also much to be doubted, whether the amalgam will discharge itself completely in the short space between succeeding decomposition chambers, in view of the well-known tenacity with which it retains the alkali metal. It will probably become more concentrated in each succeeding chamber, leading to a correspondingly increased loss of alkali by reactions taking place there.

Production of Hydroxides and Oxides of Metals by Electrolysis.—F. F. Hunt, New Brighton, N. Y. Patent 748,609 January 5, 1904. Application filed January 22, 1903.

The process consists in the electrolysis between electrodes of the same metal, the hydroxide or oxide of which is desired of a suitable electrolyte, which consists preferably "of a neutral solution and of an alkali or alkaline earth, whose acid radical will form a salt of the metal of the anode which is soluble in the electrolyte." The polarity of the electrodes is reversed at suitable intervals. During electrolysis soluble salts are produced at the anode, which react with the caustic alkali formed around the cathode to produce the hydroxide. In the production of hydroxide of tin a five to ten per cent solution of sodium chloride is electrolyzed at a temperature between 30° and 40° C., with a current density of from twelve to fifteen amperes per square foot of anode. The voltage between the electrodes is 2½ volts, and the polarity of the electrodes is reversed at intervals of about one minute. The writer, in following a similar line of procedure as that outlined in the specification, in experiments carried out several years ago, experienced a great deal of trouble from the deposit sticking to the electrode on reversal of the current, causing a great increase in resistance and falling off in yield.

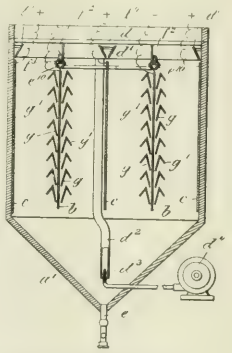


FIG. 4. CELL FOR GOLD EXTRACTION.

Process and Apparatus of Extracting Precious Metals by Electrode.—F. A. Feldkamp, Newark, N. J. 749,855, Jan- and 749,844, January 19, 1904. Application filed October 25, 1902.

The apparatus is illustrated in Fig. 4, and consists of an electrolyzing tank *a*, with a printed bottom a′ provided with a discharge door. Alternating cathodes *b* and anodes *c* are vertically suspended in the tank. An ore pulp tank *d* extends across the upper part of tank *a*, which communicates with a series of launders d', the bottom of which is perforated, and which are disposed right above the anodes *c*. The pulp in flowing out of these perforations flows along the anodes and accumulates in the bottom of the apparatus, whence it is forced up again through pipe d^2 by means of an air-blower d^4 and nozzle d^3. It then circulates again through the apparatus as before, until the values are leached out by the solvent, preferably cyanide of potassium, mixed with the pulp. The cathodes *b* are kept amalgamated by a stream of mercury which falls upon them from a number of perforated iron troughs e^{10} arranged directly above them. A distributing device is also provided. In order to insure a perfect amalgamation of the cathodes, and to prevent mercury from reaching the anodes, a number of deflectors *g* are provided, which have a downwardly inclined guard g^1 on the side towards the anodes, in order to direct the descending stream of pulp towards them. The mercury falls down into the pointed bottom and is forced up again by an air-lift, which delivers it into a pot provided with an amalgam filter. From there it flows in a sinuous way through a cleaning tank filled with dilute sulphuric acid, whence it is returned into the distributing trough, and begins its circulation again. When the values have all been extracted from the pulp, the latter is discharged through the discharge door in the bottom. The electrolysis of the cyanide solution takes place, the values being dissolved out of the pulp passing the anodes and precipitating as amalgam upon the cathodes. The coarser particles of gold are claimed to be immediately amalgamated and retained on the cloth filter mentioned above. The amalgam which accumulates on the plates is from time to time removed and treated in the usual manner.

Storage Batteries.

Method of Producing Electrodes for Storage Batteries.—F. A. Feldkamp, Newark. Patent 748,940, January 5, 1904. Application filed April 17, 1903.

In carrying out his method, the inventor places one or more pieces of porous material, such as linen, cotton, cheese cloth, etc., against a conducting plate of preferably lead and sews them to the plate. Zinc dust or granular zinc is then sprinkled on the material until it becomes thoroughly impregnated. The plate is then suspended in a solution of acetate or nitrate of lead, whereupon it is claimed that the lead separates out in spongy form from the solution on meeting the particles of zinc, and becomes thoroughly imbedded in the material, the plate being thus substantially converted into a lead plate. The plate is then rinsed in clear water and preferably passed between a set of rolls to remove the moisture and compress the deposit to some extent. Several modifications of the above treatment are given in the specification.

Process of Producing Electrodes for Storage Batteries and Electrode. F. A. Feldkamp, Newark, N. J. 749,855, January 19, 1904. Application filed May 19, 1903.

The process consists in taking a lead plate or grid, and wrapping it in such material as mull linen, mosquito netting, or similar material, mosquito-netting with from eight to ten threads each way per square inch being stated to be admirably adapted for the purpose. Three layers of the material are wound on each side and sewed fast to the plate. The active material is then applied in a plastic or semi-plastic condition to one side of the plate and forced into the porous material by pressure, until it fills the openings in the plate or grid, and comes to the surface on the other side of the plate. The latter side is then similarly treated, the result of the procedure being a plate of extreme hardness, the active material of which is prevented from peeling, blistering, etc.

Electrode.—Rudolf Hager, Berlin, Germany. Patent 749,185, January 12, 1904. Application filed January 31, 1901.

The electrode described in this specification is built up of a number of superimposed V-shaped channels, connected at several places by upright strips of lead. The channels are bent into a circle, the inventor claiming that deformations and tensions in the electrodes can be obviated if each channel, instead of being a complete ring, is slit at one point along its circumference. Modifications of channels, *i.e.*, such with corrugated or slanting walls, and spiral-shaped channels, are also described.

Battery Plate.—Oskar Frank, Detroit. Patent 749,785, January 19, 1904. Application filed May 2, 1903.

The plate consists of a rectangular frame, with the usual connecting lug, and a series of vertical and horizontal bars. The vertical bars have the same thickness as the plate, while the horizontal bars are of triangular cross-section and about one-half the thickness of the plate. They are staggered on opposite sides of the plate with the base of the triangle flush with the faces of the plate upon opposite sides. In casting the plates, thin webs connect the bases of opposing triangular ribs, which webs are then punched through from opposing sides to form triangular hooks, which are claimed to be highly important in holding the active material.

Electrical Accumulator.—Ch. P. Elieson and V. de Bobinsky, Paris, France. Patent 12,195, Reissue. Original 692,433, February 4, 1902. Application for reissue filed October 26, 1903.

The plates of the accumulator consist of two columns composed of a number of lead strips, which are alternately corrugated and flat. A compound strengthening rib is provided in the middle.

Plate for Storage Batteries.—Joseph Bijur, New York. Patent 751,046, February 2, 1904. Application filed March 31, 1902.

The plate shown in the specification is provided with a number of panels, which are preferably cast separately from the rest of the plate. The panels are composed of a number of vertical strips with cross members supporting them. The spaces between the strips are narrower at their ends, thus strengthening the juncture between the strip and the cross members. The plate is of the Planté type, large, active area, great strength, freedom of the active strips to elongate without causing strains or buckling the frame and freedom of circulation of the electrolyte being among the advantages claimed for it.

Storage Battery Plate.—Charles B. Askew, Chicago, Ill. Patent 751,772, February 9, 1904. Application filed May 30, 1903.

The plate is constructed with retaining and supporting projections for the active material, the upper and lower faces of which are disposed at right angles to the mean plane of the plate body or grid, and are also provided with key apertures extending entirely through the grid, so that when pasted on both sides, the active material upon opposite sides of the plate will be keyed together to afford lateral support to it.

Electric Battery.—W. S. Bryan, Cincinnati, Ohio. Patent 750,250, January 26, 1904. Application filed September 28, 1903.

The cell is constructed with a containing jar at the bottom which is provided with an air pressure pipe. The electrodes are arranged on top of the containing jar. When the battery is not in use, the liquid is contained in the jar. It is forced up by air pressure, by connecting the above tube with a source of compressed air, when it is desired to start the battery.

Storage Battery Plate.—Joseph Bijur, New York. Patent 744,895, November 24, 1903. Application filed August 14, 1900.

The plate is intended for the Planté type of storage batteries, and consists of a series of panels, which are composed of minute ribbons of lead, lying parallel with each other, and united at their ends into ribs or supports of the plate. Preferably alternate strips are slightly corrugated to permit the free circulation of the electrolyte. A method is outlined in the specification by which the ends of the strips are fused into the ribs of the plate.

Accumulator Plate.—F. W. Buehne, Freiburg, Germany. Patent 745,274, November 24, 1903. Application filed October 6, 1900.

The plate consists of a grid, which supports a material formed of a felted mass of long, fine-cut filaments of metal. The metal fibres lie across one another in all directions, and are lightly compressed generally, but more firmly compressed along certain lines, so as to give more rigidity to the mass. The entire plate may be made of a single long, uniformly cut, felted metal filament.

GALVANIC ELEMENTS.

Galvanic Battery.—D. L. Winters, Chicago. Patent 744,989, November 24, 1903. Application filed October 5, 1903.

The invention has for its object to provide a simple structural arrangement, by means of which the positive and negative electrodes of batteries can be connected in series with but little change in the terminal line connection. A mechanical arrangment for this purpose is described in detail in the specification.

Pocket Battery.—W. Heym, Berlin, Germany. Patent 744,758, November, 24, 1903. Application filed August 15, 1903.

The inventor claims the combination of two holders put together so as to form a vessel, each holder containing an active mass and a metal strip, and having a contraction, with an electrolyte filled in the space between the two holders, and a seal above the contraction.

Flexible Connector for Batteries.—Patrick Kennedy, New York. Patent 745,193, November 24, 1903. Application filed June 30, 1903.

The connector comprises a socket piece of preferably a compound of lead and antimony which is not affected by acid fumes. It is provided with a head which contains a projecting screw of harder metal, the end of which is fastened in the head. A nut of the same metal as the socket piece is provided, which in its interior contains a screw-threaded block of harder metal, intended to engage with the screw on the socket piece.

Exciting Compound for Batteries.—A. J. Marschall, Little Falls, N. Y. Patent 750,871, February 2, 1904. Application filed May 21, 1903.

The battery fluid consists of water, 100 parts by weight; zinc chloride, 80 parts; ammonium chloride, 6 parts. The inventor claims an exciting compound for batteries, consisting of a solution of zinc chloride and ammonium chloride, the zinc chloride being in excess of the ammonium chloride.

MISCELLANEOUS.

Process of Electrolytically Purifying Juices.—A. Kollrepp and A. Wohl, Charlottenburg, Germany. Patent 751,179, February 2, 1904. Application filed June 10, 1902.

The process is carried out in a tank, provided with anode plates of carbon, two anodes being used for each cathode. Situated between them are diaphragm cells, upon which are stretched parchment sheets, a sieve-like perforated iron plate at the inside of these parchment sheets forming the negative electrode. Emptying and filling of the diaphragm cell is done

by syphon tubes. The process, as applied to beet juice, obtained by diffusion, consists in precipitating with approximately 0.3 per cent of lime and carbonic acid, such salts as are insoluble in the further steps of the process. The juice is then filter-pressed and mixed with eight to ten per cent of its weight of moist saccharate of lead, containing fifty per cent of water. It is then subjected to electrolysis at a temperature of about 60° C., during active stirring, by blowing in air. At a distance of about three centimeters of the electrodes, and eight to ten volts tension, the current density is 1½ amperes per square decimeter at the beginning, and 1 ampere average. At an average ampereage of 1 ampere per square decimeter, one-fourth square meter surface of electrodes and 10 hp. hours are stated to be consumed for a cubic meter of juice in a day. The alkali is extracted by electrodialysis, the total amount of potassium hydrate diffusing to the negative electrode being stated as about one per cent of the weight of sugar purified by electrolysis. The compounds of lead of the non-sacchariferous substances obtained by electrolysis are mixed with discharged sacchariferous liquid and excess of alkali, the saccharate of lead thus obtained being separated by filter pressing.

Apparatus for Purifying Liquids.—Otto Kartzmark, Brooklyn. Patent 751,986, February 9, 1904. Application filed December 26, 1900.

The apparatus consists of a long tank with an overflow at the end leading to a settling tank. Placed within this tank is a smaller tank, open at the bottom, but so arranged that the liquid can overflow at the top. A series of detachable electrodes are supported in the smaller tank at a suitable distance above the bottom of the apparatus. The liquid is passed upwards between the electrodes, and into the larger tank, whence it flows into a settling tank.

Molding-Case for Use in Electrotyping and Process of Manufacturing Same.—W. H. Welsh, Collingswood, N. J. Patent 752,493, February 16, 1904. Application filed October 13, 1903.

The objects of the invention are to prepare the molding-case in such a manner, that the sticking of the impressionable composition of the case to the cut, half-tone, etc., while making the impression, is prevented, and to also prevent the slipping or spreading of the impressionable composition, while the impression is being made. This is attained by coating the composition with flour of copper, an impalpable powder obtained by grinding the siftings of electrodeposited copper. After this the case is passed through the ordinary steps of electroplating, i. e., making the impression, blackleading and treatment in the electrolytic bath.

Current Interrupter.—T. A. Houghton, Rochester, N. Y. Patent 745,280, November 24, 1903. Application filed April 1, 1903.

The invention relates to an interrupter of the Wehnelt type. It comprises a jar partially filled with dilute sulphuric acid, a cathode consisting of a coil of lead pipe through which water circulates, being arranged on the bottom of the jar. A cover with suitable openings for the passage of the anodes and carrying a superstructure which supports the mechanical construction for the interrupting device, is also provided. Each of the two anodes consists of small rods or wires of platinum, which are covered by insulating members in the form of glass tubes. In the operation of the interrupter a rotating motion is imparted to a shaft, which by means of two cross-heads gives an up and down reciprocating motion to the glass tubes covering the anodes, the lower ends of which in the electrolyte are thus alternately sealed and unsealed. Provision is also made whereby the circuit connected with an anode is positively broken or disconnected when the anode is sealed by its insulating member, thus directing all the current into the anode which is unsealed. The frequency of the vibrations may be varied by revolving the driving shaft at greater or less speed, and the intensity of the current may be varied by adjusting the anodes vertically or decreasing the surface of them, which is unsealed by the movement of the insulating tubes.

Apparatus for Sterilizing Water.—H. J. Wessels, Paris, France. Patent 751,886, February 9, 1904. Application filed June 22, 1903.

The ozonizers of this apparatus have electrodes which are formed of a series of points, arranged in a semi-circle a short distance above a semi-cylindrical trough of metal, the electric discharges taking place between the points and the metal. The trough is provided with a jacket of enamel and a cooling fluid circulates in the space thus formed. The ozonized air is cooled in its passage from one ozonizer to the other, and then mixed with the water to be sterilized.

SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.

Industrial Electrochemistry.

Formation of Periodates.—For some time E. Mueller has studied the electrolytic formation of periodates. He has formerly described a method in which he used a diaphragm to prevent the periodate which was formed at the anode, from reaching the cathode and being reduced again. He later found that this reduction is successfully prevented without diaphragm, if some chromate is added to the solution (the same device has also proved useful in other cases). In the *Zeit. f. Elektrochemie,* January 22, the same author now gives the following rules for producing periodates of alkalies. In normal potassuim hydroxide, which contains 0.1 per cent of the volume K_2CrO_4, and is saturated with potassium iodate, two bright platinum wires are placed as cathodes at both sides of a sheet platinum anode; with an anodic current density of 0.05 ampere per square centimeter, and, at the ordinary temperature of the room, it is possible to oxidize nearly all the iodate to periodate. The author describes a long series of experiments which were made to explain some points in the theory of the process.

Electric Furnace Processes for Nickel Production.—In an article published in *L'Ind. Electrochim.*, December, H. Becker discusses the possibility of the treatment of New Caledonian ores for the production of nickel. These ores generally contain 9 to 17 per cent protoxide of nickel, 41 to 46 silicic acid, 5 to 14 iron peroxide, 1 to 7 alumina, 6 to 9 magnesia and 8 to 16 water. There is generally much iron in the ores, so that by reduction and fusion, an alloy rich in iron is obtained. Treatment of the ores in a blast furnace produces an iron-nickel alloy, and there is no suitable method for getting the nickel out of it. The same disadvantage is in the use of the electric furnace. Moreover, carbon and silicium are also among the impurities. Heiberg has proposed to treat in the electric furnace a mixture of oxide of iron and nickel with sufficient coke and lime, to produce ferro-nickel and calcium carbide as by-product; this would be possible with pure raw materials, but not with the New Caledonian ores, which contain considerable silicium. For the refining of nickel Le Verrier has proposed to electrolyse in a diaphragm cell a solution of a double chloride

of ammonium and nickel, with the impure nickel anodes and pure nickel cathodes. The nickel is deposited upon the cathode, and the iron is separated from the electrolyte according to the degree it dissolves, either by blowing air into the anodic compartment, if the quantity is small, or by the addition of chlorine, if the quantity is large. This process has given good results in the laboratory, but has never been employed on a large scale. While the electric furnace is not applicable to the direct treatment of the New Caledonian ores, yet it may be used for the reduction of nickel oxide, obtained in the chemical process. The only difficulty is to get the nickel free from carbon. For this purpose Siemens & Halske separate the electrodes from the fused nickel by a slag of magnesia, with an addition of fluorspar. (See p. 466 of v. I., of this journal.)

Caustic Soda Industry.—The following quotation from our British contemporary, the *Chemical Trade Journal*, January 16, should interest our readers: "The American production, both of alkali and bleach, has now reached such proportions that it has to be reckoned with, and, though no immediate extension of operations is contemplated, it is very probable that we shall hear more in the near future. The Michigan Alkali Co., at Wyandotte, have been busy rebuilding the works that were destroyed by fire. It is rumored that they are now ready to start again with a production of 500 tons of ash per day, and 30 tons a day of bicarb. A large coke plant has also been added, which will supply both the No. 1 and the No. 2 works with coke and ammonia, so that it will be seen that these works are now as fully equipped as any British or Continental establishments. The No. 2 works of this company make nothing but caustic soda and cement, the production of the former amounting to over 2200 tons per month. The cement works are large enough to work up all the lime mud produced in causticising the ash. The Barberton works is running full time, and turning out 200 tons a day of soda ash, and 40 tons a day of caustic soda, from which figures it is easy to comprehend the importance of the American competition. It will be a poor lookout for the caustic soda trade of this country (England) should the makers fail to introduce such labor-saving and fuel-economizing machinery as are normally employed in the States. The Bell electrolytic alkali plant, lately installed at the works of the Pennsylvania Salt Co. (in Wyandotte, Mich.; the Bell process uses a mercury cathode), does not seem to have reached perfection. In fact, it is a long way from this, as, though they have been working on and off for over six months, they do not seem to have made much headway. Up to Christmas last, they had packed only five chambers of bleach, of an average strength of 32 per cent, and three small pots of caustic, of very good quality, but something much more than this is necessary for a satisfactory financial issue. We are not surprised at the foregoing results, as the balance sheets of our own (English) companies seem to point to the fact that there is not much difference in the results to be obtained by the application of electrolysis to the decomposition of common salts, over and above those to be obtained by the Leblanc process."

Hydroelectric Plants and Electrochemistry in France.—In the issue of January 22 of the Lond. *Elec. Review* M. Bloch describes a number of water-power plants, partly supplying electrochemical works in the district around Grenoble, which was the headquarters of the Congress de l'Houille Blanche (White Coal, meaning the waterfalls utilized for power). Various electrochemical plants are along the Romanche River, and on the Arc River. Among the most interesting is La Praz, with an output of 12,000 hp., engaged in the production of aluminium, two falls being used, of heights of 80 and 33 meters, each with a volume of 12 cubic meters per second. The author gives the following figures for the development of waterfalls in the Alpine region, and the utilization thereof:

	HP.
Aluminium works	22,536
Metallurgical factories	20,485
Chlorate of potassium works	9,000
Calcium carbide works	104,466
Sodium chlorates	13,500
Transmission of power and lighting	48,727
Various industries	19,989
Total	238,703

The power used in "various industries" is mostly furnished to paper and pulp mills, cement works, porcelain works, etc.

Calcium Carbide Plants.—In the issue of January 15 of *Jour. de l'Electrolyse*, a serial begins on calcium carbide plants. The first article deals with the two water-power plants of the Société des Carbures Métalliques in Savoy. One plant contains three 2200-hp. turbine-driven alternators, the other five 700-hp. turbine-driven alternators. The voltage of the transmission to the transformer substation at the carbide works is 15,000. No description is given of the furnace equipment of the carbide plant.

Electrolytic Soda and Chlorine Plant.—C. Domar describes in *L'Eclairage Elec.*, January 30, the plant at Gavet-Clavaux of the Société des Soudières Electrolitiques, near Grenoble. It contains two turbine-driven direct-current dynamos, giving 5000 or 2500 amperes at 75 or 150 volts respectively. No description is given of the manufacture of caustic soda and chlorine.

Electrolytic Production of Copper Wire.—Although much time and money has been spent on processes for the production of copper wire by electrolytic methods, up to the present they have not been commercially successful; a concise illustrated summary of the various attempts made in this direction is given in the January issue of *Electrochem. and Met.* The various processes are divided into these three classes: first, a traveling cathode of fine wire is thickened by electrodepositing copper on it, and is again reduced by passing through a draw-plate; second, the production of copper cylinders or discs which are cut up into strips or spirals; third, the electrodeposition of copper in the form of a strip deposited on a thread or strip wrapped around a revolving cathode.

Electromagnetic and Electrostatic Separation.—A paper on this subject was recently presented by D. Korda to the International Society of Electricians in Paris. A reprint in full begins in *L'Eclairage Elec.*, February 6 and 13. The author first discusses the electrostatic methods of Blake and Negreano and then begins to give a review of electromagnetic separators

Lectures on Electrochemical Industries.—A portion of lecture notes on electrochemistry, prepared for the Electrical Engineering Department of Columbia University, is published by F. B. Crocker and M. Arendt in the November issue of the *School of Mines Quarterly*. After a brief classification of the subject matters of electrochemistry the authors outline the following processes: Electrolytic refining of copper, electrolytic production of aluminium, caustic soda, potassium chlorate, various furnace processes, especially calcium carbide, carborundum, artificial graphite.

Soldering Aluminium.—An anonymous writer in the *Amer Machinist* of January 7 is surprised that so many people do not know how to solder aluminium. To make the solder, he uses bismuth, 10 parts; zinc, 30 parts, and pure tin, 60 parts. He advises to melt the bismuth and zinc first, then add the tin; pour the whole into molds about a foot long and about the size of a pencil. To do the soldering he uses a stick of solder, an old nickel aluminium spoke and a blow torch. The pieces to be soldered are held in a vise or any convenient place, the flame from the torch is applied to them, until they are hot enough to melt the solder, when it is applied, the surface to be soldered is then scraped with a file or scraper. "Melt the solder on to each piece and work it around with the spoke; now hold the parts together in front of the flame, move the

torch away and let them cool, and the mend will be as strong as if it never was broken."

Theoretical and Experimental.

Dielectric Constants of Solvents and Solutions.—The January issue of the *Jour. of Phys. Chemistry* contains a paper by H. E. Eggers, who has made researches in continuations of the work of Schlundt, and tested various hitherto uninvestigated solvents, mostly sulphur compounds. He found, notably in the case of nitriles, that the dielectric constant is not an additive property, but depends to a very great degree on the relative chemical structure of the molecule. In the case of the nitriles a single cyanogen radical at the end of a chain has the effect of raising the dielectric constant to an enormous degree. Two cyanogen radicals, however, in the same molecule, tend to neutralize each other, and it is only upon their separation in the molecule that the resultant raising of the inductive capacity occurs. This explains what was hitherto inexplicable, namely, the fact that while cyanogen itself has a very low specific inductive capacity, its hydrogen compound, HCN, has one of the highest dielectric constants hitherto found. and that the simple nitriles and normal sulphocyanates have high dielectric constants. The author also studied the dielectric constants of solutions resulting from the combination of various solids, with non-conducting liquids. He found that the volumetric formula advanced by Silberstein for the calculation of the dielectric constants of solutions from those of their components, while roughly approximate for solutions of liquids in liquids, is entirely inadequate when applied to solutions of solids in liquids. Only in one case, that of sulphur dissolved in carbon disulphide, did the results seem to give a clue to the dielectric constant of the solute. In cases where solvents were used with the same solute, the dielectric constants of the mixture did not indicate that the solute exerted a similar influence in each case. This phenomenon points directly to the conclusion that the dielectric constant of a solution is not a simple function of either constituent, but is due to an indefinite compound, i. e., a compound according to variable proportions, resulting from combination of the constituents.

Electrolytic Analysis.—In a Faraday Society paper, published in the January issue of *Electrochem. and Met.* A. Hollard says that the only principle involved hitherto in electrolytic analysis for the separation of elements is that which is based on the successive separation of the metals by gradual increase of the potential across the electrodes, each metal depositing itself at a potential spoken of as the potential proper to the metal. But he thinks that this principle is hardly directly applicable, since the method requires too much time, and that the only applications of this principle which have been made are the separations with very weak currents of copper and silver, of silver and bismuth, and of mercury and bismuth, that is of metals whose polarization potentials are lower than that of hydrogen. If hydrogen is evolved, the deposition of the metal is very slow and will never be complete. The author pronounces the following three principles applicable to electrolytic analysis. The first is "the reduction of the resistance of the bath by suppressing the formation of gas at the anode." This may be done by introducing "a reducing agent into the bath, such as sulphurous acid, which prevents the liberation of oxygen gas by combining with it. This suppression of gas greatly augments the conductivity of the bath; for the same potential applied to the bath the current which passes is much more intense and permits the precipitation of one of the metals on the cathode in a relatively short time." As an example, is given the separation of nickel from zinc. (The author overlooks completely that he has here to do far less with a "reduction of the resistance of the bath," but rather with an entirely new anodic reaction, resulting in a new anode potential.) The same effect may be obtained by using a soluble anode. For instance, in the case of separating nickel from zinc, he deposits nickel upon a platinum cathode, and uses a zinc anode; this is done in a diaphragm cell in which the cathodic compartment contains the mixture of nickel and zinc salts, while the anodic compartment contains a solution of magnesium sulphate. No external source of current is here necessary, since when the anode and cathode are connected by a metallic wire, the whole acts as a short-circuited galvanic cell The action can then, of course, be explained by Nernst's theory, as is shown by the author. Finally, the author says, concerning such a method, that "there is another secondary phenomenon which does not occur with nickel sulphate, but which is manifest with certain other salts. This can be discussed for the sake of completeness. We mean the migration of the salts in the course of the electrolysis from the cathode (here the platinum electrode) to the anode (here the precipitating metal). This is Hittorf's phenomenon. For each metal, then, it is necessary to find out if it forms a salt which does not show the Hittorf phenomenon, and if it is preferable to work at one temperature more than another, for the losses of concentration round the cathode (and round the anode) vary with the temperature. This method cannot be applied to every class of salt, and so is not general. It cannot be used for copper in particular, the $Cu^{\cdot\cdot}$ ions passing very rapidly to the anode cell." (The author here mixes up two entirely different phenomena, the one being electro-endosmosis or cataphoresis, due to the presence of the diaphragm, the other being the transference of the ions according to Hittorf. On account of the latter, bivalent positive Cu ions will never pass to the anode. Of course, if one electrolyses copper sulphate between copper electrodes without diaphragm, in order to exclude the phenomenon of electric endosmosis, the concentration will decrease at the cathode and increase near the anode. But the latter is the case, not because Cu ions have passed toward the anode, but because more new copper ions are formed from the anode than pass in the same time through any cross-section of the cell towards the cathode.) The second principle depends on the choice of the nature of the cathode, and has to do with the so-called overvoltage required at a given cathode to produce gaseous hydrogen. For a platinum cathode, we can arrange all the metals according to the voltage required to deposit them; they may be grouped into two classes, those in the first class requiring a smaller voltage for deposition than hydrogen, those in the second class requiring a larger voltage. Lead, tin and cadmium are in the latter class If, however, instead of a platinum cathode, we use a lead or tin or cadmium electrode, the deposition voltage of hydrogen is raised above that of lead or tin or cadmium, respectively; in other words the latter metals can now be deposited without the evolution of hydrogen. As an example, is given the separation of cadmium from zinc, by means of a cadmium cathode. The third principle is the formation of complex salts, an example being Classen's separation of antimony and tin in a concentrated solution of sodium hydrogen sulphide; the tin here passes into the state of a complex anion.

Revolving Cathodes for Electrolytic Analysis.—In the February issue of *Elektrochem. Zeitschrift* H. Paweck makes some remarks on the advantages of using a metal screen cathode for electrolytic analysis. He remarks that in the Stolberg works an amalgamated brass screen cathode is used for the electrolytic determination of zinc, the latter being weighed as amalgam. He then discusses at some length, and with the aid of illustrations various arrangements of revolving electrodes.

Quantitative Analysis.—Notes on quantitative analysis, prepared for the students in School of Mines at Columbia University, are published by E. H. Miller in the November issue of the *School of Mines Quarterly.* The article contains an introduction on some of the analytical applications of the theories of ionization, mass action and solubility product.

Electrochemical Equivalent of Silver.—It is well known that the exact determination of the electrochemical equivalent of silver is of the greatest importance, since this value is one of

the most fundamental figures on which measurements in electrical engineering are based. It is therefore quite natural that the most able scientists of all countries have been interested in careful determinations and re-determinations of this value. In this country Carhart and Guthe have highly distinguished themselves in this direction. For electrochemists we may simply point to the fact that this figure is one of those fundamental figures on which every application of Faraday's law is based (see, for instance, the article of Hering, Electrochemical Industry, 1903, page 169). The results of former investigators vary from 0.011156 (Mascart) to 0.011195 (Pellat and Leduc). An account of a redetermination by G. Van Dijk and J. Kunst is given in the *Proceed. Akad. Wet.*, Amsterdam, January 21 (and noticed in the Lond. *Elec.*, February 5). The authors used a tangent galvanometer for determining the strength of the current. Owing to the high degree of accuracy with which the constant of the instrument and the horizontal intensity of the earth's magnetic field and its space and time variations may be determined, this method is well adapted for a laboratory which has been built without iron, and in a place where no vibrations or stray currents in the earth are to be feared. The authors adopted Kohlrausch's bifilar method. The cathodes consisted of platinum, being either cup-shaped or in the form of a cylinder ending in a hemisphere. A silver rod served as an anode. Two voltameters were placed in series in order to insure that no irregularities occurred in the deposition of silver. The final mean value obtained from twenty-four measurements was 0.0111818, which the authors believe to be accurate to within one part in 10,000. (The above figures evidently give the electrochemical equivalent in decigrams per coulomb. To get it in grams per coulomb, all the figures are to be divided by 10. It may be remembered that the value adopted by the International Electrical Congress of Chicago, in 1893, was 0.001118 gram per coulomb; i. e., one ampere deposits 0.001118 gram, or 1.118 milligram of silver per second.)

Electrolytic Rectifier.—In the January issue of the *Physical Review*, S. R. Cook gives an account of a series of experiments made to investigate the reasons of the well-known behavior of the aluminium cathode. He used it in a solution of potassium aluminium sulphate and studied the behavior with varying temperatures. He considers his experiments to prove that the apparent resistance of the aluminium anode is not a true ohmic resistance, but a "resistance of transition of ions" manifesting itself in a counter e. m. f. There is formed on the aluminium surface a film either of normal aluminium hydroxide, $Al_2(OH)_6$, or, as he believes more probable, of aluminium oxide, Al_2O_3, with water of crystalization in that part of the oxide which crystallizes. This film is a very poor electric conductor, and its formation prevents the anions from reaching the conducting surface of the anode and thus discharging. When the aluminium is the cathode, hydrogen is developed; the cation finds access to the metallic surface of the aluminium plate and hydrogen is set free between the film of alumina and the metallic aluminium, thus separating the two surfaces and exposing the metallic aluminium to further action of the cations. As long as the applied e. m. f. remains below a certain critical value which depends upon the temperature, the film formed upon the aluminium anode is very hard, whitish, compact, non-crystalline and apparently insoluble in the electrolyte When, however, the applied voltage is greater than the critical value, the film changes from a white non-crystalline substance to a dark crystalline substance at certain parts of the plate. In crystallizing, free metallic surfaces are exposed to the action of the anions which now may be discharged and current can pass. The value of the critical pressure, and also the counter e. m. f. depend upon the temperature. The critical e. m. f. for one degree is approximately 47 volts, and for 48° only 22 volts. The counter e. m. f. increases with the increase of temperature.

Electric Resistance Furnace for the Laboratory.—In form of a reply to the article of Guntz (abstracted in the Synopsis, January, 1904, p. 29) W. C. Heraeus gives in the *Jour. de Phys. Chim.*, January, some details of his own laboratory furnace in which, as will be remembered, very thin platinum foil is used for the heating coil. His furnaces do not consume considerably more current than that of Guntz, but some power losses cannot be avoided in a furnace which shall be suitable for general laboratory work. The heating tube on which the platinum foil is wound has only a small mass which assumes nearly instantaneously the temperature of the platinum foil, and follows immediately all changes of its temperature. This allows rapid and exact regulation of the temperature.

The Constitution of Salt Solutions.—It becomes clearer every day that the ideas on the constitution of salt solutions, as they were generally held on the basis of the electrolytic dissociation theory, cannot be strictly correct, as they are too simple. Hittorf had already shown in 1859 that the salt $CdCl_2$ contains in solution besides the simple ions Cd (bivalent positive) and Cl (monovalent negative), also complex ions of the general formula $(CdCl_2)n$ (Cl')m. The possibility of the formation of such complex ions has later been mostly overlooked, although Arrhenius, Abegg and Bodlaender and Biltz were led to similar conclusions. In this connection a paper by R. Abegg, based on experiments of S. Labendzinski, is quite interesting. It shows that such complex ions exist even in simple solutions to a considerable degree. One of the main results is that the old disagreement between theory and practice in the case of Ostwald's law for the relation between conductivity and dilution may now be explained. On the other hand, the great simplicity of ideas which was one of the beauties of the dissociation theory, is to be given up. The paper of Abegg is published in *Zeit. f. Elektrochemie*, January 29.

Batteries.

Action of Light Upon the Formation of Accumulator Plates.—Some peculiar observations, which, however, are evidently of scientific interest only, are recorded by D. Tommasi in *L'Eclairage Elec.*, February 13 (also in Lond. *Elec. Rev.*, February 12). In short, he found that the negative plates of an accumulator form more rapidly in light than in the dark, while the positive plates form more quickly in the dark than in the light, other things being equal. Also, the positives formed in the dark are characterized by a dark-brown appearance, those formed in the light being of a reddish-brown color. This difference of shades persists during several charges, but eventually disappears entirely. Thus the reddish color of the positives which have been exposed to the light becomes darker and darker, until it attains the brown tint of the positives which have been formed in the dark. The capacity of an accumulator, whether charged in the light or in the dark, was found to be practically unchanged.

Accumulator Traction.—It is estimated that of all storage batteries, now manufactured, 75 per cent are used as stationary batteries in electric central stations and sub-stations. The increased interest in automobilism, and the obvious advantages of the electric automobile have created a new and promising field for a light battery. On the other hand, for traction on rails, the storage battery has not succeeded in holding its own, in spite of a great many attempts. Some data given in the *Elek. Zeit.* of Feb. 11, by P. Lanino on storage battery traction of some Italian lines, show that the system was there a success from a technical and especially from a financial standpoint. On the line from Milan to Monza the cost of operation was 16.25 cents per car kilometer (the cars having a weight of 58 tons), the energy consumption was 65 watt hours per ton kilometer, the cost of maintenance of the plates was 7 cents per ton kilometer. The operation of the system was discontinued since it was not elastic enough, the traffic being too heavy and not enough motor cars being available on holidays. On the line from Bolgna to San Felice the cars had a weight of 15 tons, and could carry 75 passengers. The cost

of maintenance of the battery was 6.075 cents, and the total cost of operation 11.15 cents per train kilometer. In spite of the results which were good beyond expectation, the accumulator system was discontinued partly on the desire of some influential officials of the company, and partly because the service was not sufficiently elastic, as in the other case.

Edison Nickel-Iron Storage Battery.—W. Hibbert's paper, which we have already noticed, was recently discussed at length before the (British) Inst. Elec. Eng. A full report is given in the *Lond. Elec.*, February 5. W. Hibbert mentioned the recent improvement due to the use of twice as many nickel-plates as iron plates, and gave the curves for the new cell which were already published in our January issue, p. 37. J. A. Fleming gave an account of the tests which he has made with the older type, and remarked that Janet, Hospitalier, Finzi, Hibbert and himself, had all practically obtained the same results. E. J. Wade discussed the probable reasons why the voltage drops gradually during discharge, the curves for the Edison cell closely resembling those of a lead cell. Yet, the reason cannot be exactly the same in both cases. He thinks that in both cases the first rapid fall is due to the peroxide products in the cell, and the final fall to the specific resistance of the active material, while he attributes the intermediate fall to slight variations in the concentrations of the electrolyte. (This explanation seems questionable. Concentration changes will develop in the pores of both plates of the Edison cell, but the concentration will increase in one plate and decrease in the other, and if we keep on with the same rate of discharge, we should expect that soon a stationary condition would be reached in which further increase and decrease of concentration would be annihilated by diffusion. It can be shown that the variation of the e. m. f. proper, due to these concentration changes, is small. On the other hand, the resistance of the active material must change continually and quite considerably. The resistance is quite a complex function, since the oxidation or reduction of the active material here proceeds from the outside to the inside of the metallic particles in the briquettes, but also of the dilute or concentrated electrolyte in the pores.) H. L. Joly gave some interesting results of tests which had been quite disinterested and uninspired. He did not know of any cell in which Peukert's coefficient is so low, and came to the conclusion that it is perfectly safe to take it at 1.1, which is the lowest figure on record. The results of his charging tests are given in Fig. 1. Curve A shows the rise in p. d. when charging at 100 amperes, curve B when charging at 60 amperes, and curve C at 30 amperes. Immediately under these three curves are two others, that marked D showing the rise of e. m. f. corresponding to a charging current of 100 amperes, and that marked E to charging currents of 60 and 30 amperes. Now, it will be seen that the p. d. remains practically constant after the cell has received 250 ampere hours, but the e. m. f. continues to rise, and this led him to think that the e. m. f. was not a true indication of the state of affairs. Moreover, the curves A', B', C' which represented respectively the rate of evolution of gas, when charging at 100, 60 and 30 amperes, in liters per hour, showed a downward tendency after the 250-ampere-hour point. This was probably due to a diminution in the quantity of free H_2O in the electrolyte, and everything tended to show that the cell was fully charged when it had received 250 ampere hours, and it was, therefore, unnecessary to go as far as 300 ampere hours. The curve F represents the p. d. between the iron electrode and the case at the 100 ampere rate, G, the p. d. at the 30 and 60 ampere rates, and H showed the variation of p. d. between the nickel electrode and the case at all three rates of charge. Fig. 2 shows the comparative behavior of the plates tested by means of an auxiliary electrode; cadmium was first tried, but the use of the container itself gave more reliable figures. This method showed a drop on the negative electrode, and a rapid recovery, at the same time as the p. d. dropped on the nickel plate and settled at the lower level. W. R. Cooper and W. H. Patchell also participated in the discussion.

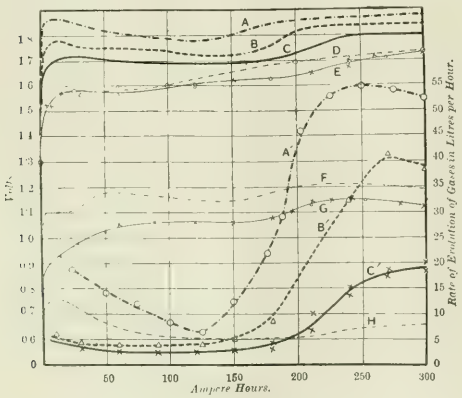


FIG. 1.—CHARGE CURVES OF EDISON BATTERY.

In *L'Eclairage Elec.*, February 6, R. Jouaust publishes a long article on the Edison accumulator, giving nothing new, but summing up the existing extended literature quite concisely and fairly, and dealing at some length with the chemistry of the subject. He mentions that in searching for a new and light accumulator, Krieger, Michalowski, Gahl and Jungner had made nickel oxide and an electrolyte of sodium hydroxide the subject of patents, but "of all these cells only the last one was followed up by an attempt at realization." "The Jungner battery has never been the object of official tests in France, and the results obtained by Schoop, and published in *Elek. Zeit.* (see Electrochemical Industry, vol. 1, 1903, p. 465) do not seem to be favorable to that cell, the capacity of which would be only 18.6 watt hours per kg. for a discharge rate of 1.2 watts per kg." His final conclusion on the Edison battery is that, in spite of its relatively low efficiency, it will apparently render great services in all cases in which one needs a battery of high discharge rates, especially on automobiles and submarine boats; and this is the object for which it was designed by its inventor.

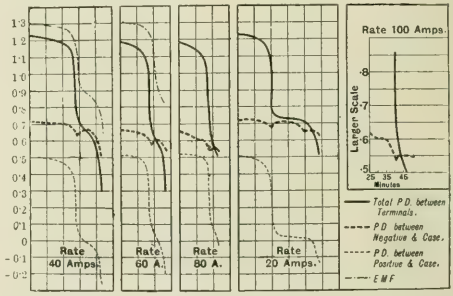
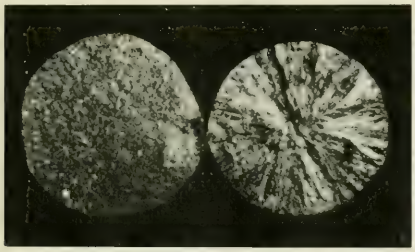


FIG. 2.—BEHAVIOR OF INDIVIDUAL PLATES AT END OF DISCHARGE.

Jungner Battery.—Some data on the Jungner battery which is being developed by the Koelner Akkumulatoren Werke, Gottfried Hagen, are given by H. L. Joly on the basis of information received from M. U. Schoop of that company, in the January issue of *Electrochem. and Met.* In the construction of the Jungner plates sheet steel 2 mm. thick, nickel-plated and perforated, with the burrs retained, is folded on itself so as to form pockets. The perforations are arranged so as to leave solid metal where the sheet is folded. Two, three, or

more pockets are placed side by side, and clipped top and bottom by nickeled steel bands, which may be soldered, and are brought together to a connecting bar, provided with a screw terminal, upon which they were at first fixed by screws. This experimental construction has, however, been improved. At present removable airtight lids of stamped steel, with rubber joints and valve are used. The following results were obtained by Schoop with a cell 273 mm. high (with terminals 303 mm.), 77 mm. wide and 86 mm. long, the total weight being 3.106 kilograms. For a discharge rate of 20, 10 and 1 amperes, the capacity was 30, 39.5 and 48.0 ampere hours, and 30.9, 44.24, 57.6 watt hours. (That is, for the low discharge rate of ampere, a capacity of 18.5 watt hours per kilogram, or 8.4 watt hours per pound, which is far below that of the Edison cell.) It is said that the capacity obtained at 20 amperes, with a more recent cell (of the same weight?) was 50 ampere hours. Schoop and Jungner have succeeded in making a gelatinous alkaline electrolyte for their cells. The priority question between Edison and Jungner is discussed, and an opinion of G. von Knorre is given, who expresses himself strongly in favor of Jungner.

Structure of Zinc Electrodes.—An interesting example of the influence of the structure of zinc on the action of zinc electrodes in primary cells is described by R. Job in the *Iron and Steel Metallurgist* of February. The zincs of some gravity cells, used in connection with railway track signals, had worn away very rapidly in service, and had averaged only about one-third of the life usual under the given conditions. As the metal dissolved, relatively large portions of the zinc became loosened and dropped upon the copper sulphate crystals beneath, and thus reduced the efficiency of the cell. The zinc, upon analysis, was found of good quality, but upon examining the structure, a very large, coarse granular form was found due to pouring the zinc into the mould at a relatively high temperature. The fracture is shown to the right of the adjoining illustration. Some of the same zinc was then taken,



STRUCTURE OF BATTERY LINES.

melted and poured into the mould at a fairly low temperature, giving the structure represented by the fracture to the left in the illustration. Upon putting these zincs in service, under the same conditions as previously, no scaling off occurred, and the zinc wore away gradually, giving the normal life. The defective service of the coarse-grained zinc is easily explained by assuming that under the electrolytic action the liquid penetrated along the surfaces of the crystals, and, as action progressed, gradually dissolved the metal along such surfaces and thus finally resulted in the scale. In the fine-grained zinc no such action was possible, owing to the small size of the crystals. This is another example illustrating the fact—which is often not sufficiently appreciated—that chemical composition is not everything, the structure playing often an important part in the application of metals to pracical uses.

Franklin Institute.—On March 3, Mr. William M. Scott, electrical engineer of the Cutter Electric & Manufacturing Co., of Philadelphia, will deliver a lecture on circuit breakers, and Mr. J. Hart Robertson on the diaphragm storage battery.

Correspondence.

MERCURY CATHODE CELL.

To the Editor of Electrochemical Industry:

Sir—Your issue of December, 1902, has just come to my notice, containing therein, on page 132, a description of my electrolytic cell. To the casual reader, Dr. Scholl gives an unfavorable impression by his analysis, which is in part due to his not having read the drawings correctly. The wires shown for moving the sweep do not pass through the electrolyte at any point and were never designed to do so, although the cut shown seems so to indicate. These wires run under the inclined planes, which serve to direct the amalgam into the discharge pipes.

The objection he makes to the protection of the amalgam in the traps is of very small importance, if of any, as the reaction in a small pipe is inconsiderable to that of the main body of mercury. By the auxiliary circuit they are equally protected. In fact the amalgam can be enriched after reaching the pipe, if it comes in poor enough.

The cell was not designed from theoretical or laboratory conditions alone, but is the outcome of practical experience.

Arthur E. Truesdell.

Pittsfield, Mass.

AMERICAN ELECTROCHEMICAL SOCIETY ELECTION.

To the Editor of Electrochemical Industry:

Sir—In common with most of the directors of the American Electrochemical Society I signed a petition for a constitutional amendment, making the president, vice-presidents and managers ineligible for re-election. I must therefore decline to be a candidate for re-election to the office of vice-president, for which, I am officially informed, I have been nominated.

At the same time, in view of the very handsome vote which my friends have cast for me in nomination for the presidency of the society, and of the fact that the board of directors are not endorsing any one for that office, I announce myself as a candidate for the presidency.

Henry S. Carhart.

Ann Arbor, Mich.

Book Reviews.

Kalender Fuer Elektrochemiker, Sowie Technische Chemiker und Physiker, 1904. By Dr. A. Neuburger. Published by M. Krayn, Berlin. Price, $1.35.

The "Kalender fuer Elektrochemiker, 1904," shows a vast improvement over its edition of 1903, and it is gradually working itself into a book which will be a "vade mecum" to the chemist and electrochemist. Many of the tables have been revised and others greatly enlarged, yet there is in more than one case margin for further improvements. The tables on the "minima potentials of decomposition" show a decided improvement over last year's edition, also many of the other tables show signs of improvement. A new logarithm table has been added to the mathematical section, and Dr. Neuburger has included the fundamental formulæ for differential and integral calculus, which electrochemists can make good use of. Dr. Neuburger would do well to omit the first 80 pages, which are inserted for diary, or fill them up with more important matter. Citations are in many cases missing, and when mentioned are not fully enough quoted, to make further use of. In the preface Dr. Neuburger requests those interested in the science, to give him advice, as to where the calendar is open for improvement, and how it might be improved. We hope that all electrochemists, each in their special branch, will help the editor in his effort to perfect this book.

Iron, Steel, and Other Alloys. By Henry M. Howe, Boston: Sauveur & Whiting; 457 pages. Price, $5.00.

The preface states that this work is intended to give to technical students and practitioners a systematic account of the metallography of iron, and more particularly to expose to them the present "solution" theory of the constitution of iron, and of alloys in general. In pursuance of this aim, the chapters of the book deal with the following subjects: Cooling Curves, Freezing-point Curves, Constitution of Binary Alloys, forming no definite chemical compound; Constitution of Alloys forming definite chemical compounds; the Metallography of Iron and Steel, the Heat Treatment of Steel and Cast-iron, the Phase Rule, and closes with chapters on Progress in the Manufacture of Iron and Steel from 1880 to 1900, the Blast Furnace, and Metallurgical Gas Furnaces.

The first sentence of the preface is an apology for the heterogeneousness of the book, and in this respect the author forestalls criticism of its greatest defect. In order to express accurately in the title the full scope of the work, the author must needs have copied after the title pages of a fifteenth century treatise on theology, and given as a title a symposium of the chapter headings.

However, all that is in the book is good, though of different degrees of excellence. The chapters on cooling curves, freezing-point curves, the constitution of the two classes of alloys, and the phase rule are carefully, painstakingly and lucidly written, in a manner which will make the subjects clear to anyone who will carefully study the text. The chapter on the metallography of iron and steel is exhaustive of the subject, and of the reader. It is too painstakingly elaborated, with consequent loss of force and clearness, and, in many cases, with no sharp line drawn between the facts of the subject and conjecture. The coining of such terms as *Aeolic* and *Hypo-aeolic* steels is a misdirection of energy, for such terms are too pedantic and too little expressive to find any enduring place in the literature of this art, and still less in its working nomenclature. This chapter is clearly overdone. The subject of the heat treatment of iron and steel is more satisfactory, where it touches on the facts of the subject, and more practical in its bearing. It contains much valuable information for anyone who has to study or handle iron or steel, its sixty-four pages giving a thorough treatment of the subject in a scientific manner.

The three concluding chapters contain much information which would supplement and bring up to date our text-books on iron and steel manufacture, together with some elementary presentations of the principles of the subject which are too brief to be of much use to anyone except the most casual, untechnical reader. Taken together, they are a sort of metallurgical *olla podrida*.

There is one promise in the title, brief as the latter is, which is not fulfilled in the book; viz., the "Other Alloys." One would expect, from that, a systematic discussion of the constitution of other metallic alloys than those contained in iron and steel—(such a treatise is badly needed, and a large amount of scattered material for its compiliation exists in the recent volumes of our scientific journals)—but, alas, there is to be found in the book only an incidental reference to a few of the non-ferrous alloys, and the needed treatise on the "Other Alloys" is still to be written.

As we may have appeared harsh in indicating the shortcomings or defects of Prof. Howe's book, we repeat again that a great deal of valuable information for anyone interested in the study of iron, steel or alloys, is contained in the work, it is beautifully printed and illustrated, and can be heartily recommended as well worth reading, and studying.

Storage Battery Engineering. By Lamar Lyndon. New York: McGraw Publishing Company. Price, $3.00.

The appearance of this book has been welcomed by many who have to do with storage batteries. It fills a need in the literature on the engineering practice of the lead cell. The chapters on boosters are specially noteworthy, since it is there the first time that the construction and use of boosters has been fully described in a book on storage batteries. This is creditable, since booster systems have been developed to a high degree of perfection, especially in this country. The manner in which the author deals with the subject shows distinctly his experience in this line.

Concerning the theory of the lead cell there are some points to which exception might be taken. For example, it is generally believed that the reaction in the lead accumulator is represented by the equation

$$PbO_2 + Pb + 2H_2SO_4 = 2PbSO_4 + 2H_2O$$

not only for very small current densities, but also for those used in practical work, and that the changes in the acid density during charge and discharge may be derived from this formula. Of course it must here be borne in mind that the hydrometer does not show the average specific gravity of the total electrolyte in a cell, since the exchange of acid by diffusion between the pores of the plates and the outside electrolyte is not instantaneous. It may be recalled that about a year ago Dr. Sieg, in his German book on the lead accumulator, published measurements which appeared to be contradictory to the above formula. Afterwards, however, Mr. M. U. Shoop published an article in the *Electrotechnische Zeitschrift*, showing that if one takes into account that the exchange of acid requires some time dependent upon the type of the plate, Dr. Sieg's results are not contradictory to the above formula.

In the chapter on the Planté formation the author has carefully collected patents as the only literature on this subject. Of course, this cannot give a good idea of the useful processes, since for this branch of storage-battery engineering, it is at least as true as for others, that almost all the patents are worthless. The few experiments published recently in Germany and referred to by the author, do not give any better idea about the value of a method of formation, as they do not show results for chemicals in practical use as forming agents. Therefore, this chapter cannot be considered quite satisfactory, although allowance must be made for the difficulties in its preparation.

Local action of the plates, both positive and negative, is mentioned. To explain the latter, the voltage at which hydrogen is developed at different metals should be taken into account, as is done, for instance, by Dolezalek in his book. The difference of the hydrogen developing voltage or "overvoltage," as it is called, of lead and metallic impurities accounts completely for all phenomena of local action on the negative plate. There is no local action between grid and spongy lead unless the first consists of impure lead, and the formation of spongy lead from the grid itself does not prevent local action.

But these theoretical errors, which are very few, do not lessen the value of the book, particularly as its subject is storage battery engineering, while the theory of the accumulator is not its most essential part. As a whole, the book must be called a very useful addition to our literature on the lead accumulator.

Current Notes.

Electrometallurgy of Iron and Steel.—We are informed that the German patent of M. Gin (whose process was described by Mr. Bennie in our issue of January, 1904, page 20) has been sold, and the process will be exploited upon an industrial scale at Plattenberg, within about four months. We are also informed that Messrs. Keller, Leleux & Cie (whose process was described in our issues of January, 1903, p. 162, and August, 1903, p. 470) are contemplating a large works in this country, to install and operate electric furnaces for the production of steel. The industry moves apace.

Zinc White.—In a London daily paper it is stated that Sir William Ramsay and Prof. E. Ellershausen have succeeded in obtaining, by a new process invented by Prof. Ellershausen and Mr. R. W. Western, zinc white worth £30 ($146) a ton from the refuse heaps of the Hafua mines in Wales. Throughout Wales there are scores of mines, closed because it does not pay to work them. All these mines have miniature mountains of debris, or "tailings," at the surface. There are millions of tons of this unregarded material, which mine owners have hitherto looked upon as an unavoidable nuisance. White lead frequently takes the place of zinc white, and very little zinc white is made in Great Britain. Wales found the process o making it from "spelter"—which itself costs £21 ($102.20) per ton—too expensive to leave a fair margin of profit. Hence, the present dreary succession of abandoned mines, some of them holding machinery worth many thousands of pounds. But zinc white is indispensable in certain industries; thus England imports annually from Germany, Belgium, and the United States some 200,000 tons. "By the new process the expensively obtained spelter is entirely dispensed with. The zinc white is taken direct from the ore, which costs but a tenth the sum; more, as Sir William Ramsay and the other professors showed, the very refuse of the mines can be made to yield a substantial amount of the material. From about 15 tons of the rubbish 1 ton of zinc white can be extracted. As the zinc white was rapidly evolved from the crude mineral without the elaborate and roundabout methods of the spelter system, Sir William Ramsay exclaimed, with a smile of surprise, 'A pretty process, indeed!' 'I do not see why a new era of prosperity should not dawn for Wales,' the distinguished scientist remarked."

Carbureted Air Light.—A recent consular report states that Dr. Hugh Marshall, of Edinburgh, has invented another method of using carbureted air for lighting. It is an improvement upon the form of lamp devised by M. Naum Notkin, of Moscow, in which carbureted air was obtained by employing paper pulp saturated with gasoline to produce the vapor required. In this Notkin "gravity" lamp the carbureted air, being denser than air itself, flowed from a higher to a lower level, instead of ascending like coal gas, and could therefore be poured from one vessel to another, like a liquid. In the Marshall lamp the necessary current of air through the carbureter is not maintained by the effect of gravity, but by means of the draft from the lamp chimney. It is thus possible to have the body of the lamp below the actual burner. To reduce the manipulation necessary with such a lamp when used for incandescent lighting, Dr. Marshall has invented a form of burner tube, which is sunk axially into the body of the containing vessel, and which enables the user to regulate the mixture of vapor and air to a nicety by simply rotating the tube in one direction or the other. The new method of using carbureted air has been applied by Dr. Marshall to various types of lamps —table and portable hanging, basket, and also in lantern form for outdoor lighting. These show a brilliant incandescent light, without any liquid or wicks being used, and are free from smell or smoke. Dr. Marshall claims also that carbureted air can be supplied all over a house without danger or complicated processes, and that the gas can be applied to other purposes than lighting, such as for heating and motive power.

THE USE OF CAUSTIC POTASH IN ELECTROPLATING SHOPS.

The success of an electroplating operation depends, not only upon the use of the proper solution and current density, but just as much on the cleanliness of the surface of the article which is to be plated. This surface should be absolutely free from all grease and dirt. While this is a general rule, it applies with special force to nickel-plating, since an electrolytic nickel deposit has always some tendency to peel off (if proper precautions are not taken) and since the chemical nature of the ordinary solutions used in nickel-plating, is not such as to have a dissolving action on grease. But what applies to nickel, applies more or less to every plating process, and it may be correctly stated that grease is one of the worst enemies which every electroplater has to meet. This is, of course, well known, and every practical electroplater knows how dangerous it is to touch the article to be plated with the hands, before it is placed in the plating bath, since a very thin film of grease, thus imparted to the surface, would prevent the full success of the plating operation.

The good condition of the bath, in which the article is first placed, in order to free its surface from grease or dirt, is therefore of just as much importance as the plating bath itself. For the removal of grease, a caustic soda solution is often used, but caustic potash is now coming into more extended use, since its action is more rapid and powerful than that of soda. Besides, the soap formed by the action of the caustic potash upon the grease is very easily soluble in the solution, so that all grease spots are easily removed, and the surface is perfectly cleaned.

If a caustic soda solution is used, the articles are being cleaned slowly, and, in many cases it is necessary to use other cleaning ingredients after the article has left the cleaning bath. This is not necessary with caustic potash. It is stated that a large concern recently replaced a 20° Baumé solution of caustic soda by a 3° Baumé solution of caustic potash, and the result was that the cleaning process was much quickened, improved and, besides, cheapened.

The Roberts Chemical Co., of Niagara Falls, N. Y., make a specialty of supplying caustic potash to electroplaters, putting it up either in solid or liquid form, the latter in carboys, because some platers find it more convenient in this form.

SILICON-COPPER IN THE BRASS FOUNDRY.

In our issue of October, 1903, page 498, we noticed briefly the plant of the Cowles Electric Smelting & Aluminum Co. at Lockport, N. Y., which contains much of historical interest with respect to electric smelting, while at present the main output of the plant is mostly silicon-copper. In the following the use of silicon-copper in the foundry for producing the highest grades of brass, copper and bronze castings will be discussed, but we may first say a few words on the method of its manufacture. In an electric furnace, principally of the same type which was used by the two brothers, E. H. and A. H. Cowles in their early experiments, the original charge is melted to produce an alloy of silicon and copper; to bring this alloy afterwards to standard composition, it is remelted with such additions as may be necessary.

Every foundryman knows the difficulties involved in the manufacture of pure copper castings. This difficulty is due to the fact that cuprous oxide is dissolved in molten copper and the obvious remedy is to add a reducing agent which reduces the cuprous oxide to metallic copper. Phosphorus has been found to meet this purpose to some extent, but silicon-copper is more active in clarifying, refining, hardening and strengthening copper and its alloys. The reason of the action of silicon-copper is that the combination heat of silicon with copper is very high; the silicon therefore takes away quickly the oxygen from the cuprous oxide, to form silica; silicon itself is, of course, unsuitable as an addition, it is therefore added in the form of silicon-copper.

There is no violent ebullition when silicon is added to copper or copper alloys—which cannot be said of phosphorous. The silicon-copper can be introduced without the slightest danger of explosion.

A pound and a half to two pounds of silicon-copper is required for every one hundred pounds of melted copper, to produce castings clean, solid and free from blowholes, swellings, etc. Its being placed in the crucible before pouring assures a uniform fluidity and an instant reduction of the oxide of copper. The method is of great importance for copper used for

electrical purposes. Large electrical conductors, so much in demand at this time, can be cast and marketed at a far lower figure than if worked or forged from rolled copper.

Silicon-copper is also extremely useful in the manufacture of high-grade castings in tin-bronze and brass. In tin-bronze mixtures where there is a large percentage of copper, silicon-copper to the extent of from 4 to 8 ounces only is required to 100 pounds of the bronze, in order to produce perfect deoxidation. Dullness or sluggishness in brass and tin-bronze mixtures is often caused by the gases due to the oxides in the metal. The addition of a very small amount of silicon-copper, say from 2 to 4 ounces per 100 pounds, expels the gases and reduces the oxides to metal. The fluidity of the mixture is increased to a marked extent, thereby enabling one to make sharp castings.

The copper-silicon, made by the Cowles Electric Smelting & Aluminum Co., is put up in ingots weighing about 14 pounds each. The alloy is exceedingly brittle, and can be readily reduced to small pieces, in order to add it to the metal to be treated after the other ingredients are in the crucible. When added to pure copper, the silicon-copper should be placed in the crucible just before taking from the furnace. The contents should be stirred thoroughly and skimmed well before pouring.

Besides silicon-copper, the Cowles Electric Smelting & Aluminum Co. make several valuable aluminium alloys, among them aluminium alloy No. 1, for castings, containing about 90 per cent aluminium, and nickel-aluminium, which is one of the strongest and best light alloys on the market, being recommended especially for automobile gear and motor cases, etc.

FERRO-SILICON MADE IN THE ELECTRIC FURNACE.

Ferro-silicon made in the electric furnace can now be supplied as a sound and solid alloy, containing 50 per cent of silicon, without any tendency to disintegrate. The following six principal advantages are claimed for it over the ordinary alloy made in the blast furnace: greater purity; economy in cost of carriage, storage, and handling; smaller quantity to produce the same silicising effect; less cost per unit of silicon; less reduction of heat of molten metal on the addition of the ferro-silicon, and less time required for the amalgamation of the ferro-silicon with the molten metal, and consequently less consumption of fuel.

The following two tables give the typical analysis of the blast furnace alloy, in comparison with the electric furnace alloy:

Typical Analysis of Blast Furnace Alloy.		Typical Analysis of Electric Furnace Alloy.	
Silicon	10.55%	Silicon	51.80%
Iron	83.10%	Iron	40.13%
Carbon	2.36%	Carbon	.15%
Manganese	3.86%	Manganese	.08%
Sulphur	.03%	Sulphur	.003%
Phosphorus	.04%	Phosphorus	.057%
		Aluminium	1.61%
	100.00%		99.830%

A comparison between these figures is instructive. If it be required to add to any furnace charge as much silicon as is contained in 1 ton of blast furnace alloy, the impurities added at the same time are given by the corresponding percentages of one ton. But if the same quantity of silicon is required, and electric furnace alloy is used, the quantity of alloy needed is one-fifth of a ton, and therefore only one-fifth of the percentages of the impurities are added to the charge. Thus, we add, if using:

Blast Furnace Alloy.		Electric Furnace Alloy.	
Carbon	2.36% of 1 ton	Carbon	.030% of 1 ton
Manganese	3.86% " "	Manganese	.016% " "
Sulphur	.03% " "	Sulphur	.0006% " "
Phosphorus	.04% " "	Phosphorus	.0114% " "
		Aluminium	.322% " "

The extra amount of iron added in the first case, which is regarded by some users as costing nothing is an expensive economy, when confronted with the disadvantages inseparable from the introduction of its accompanying impurities, while, as regards price, silicon for silicon, there is no difference between them. Electric furnace alloy costs about five times as much as blast furnace alloy, and contains about five times as much silicon.

Steel.

When used in the manufacture of steel, whatever the process employed, the first effect of the silicon is to combine with any oxide of iron remaining in solution in the bath, and thus to prevent to formation of "red short" metal. Silicon thus added operates much more effectually than silicon left over from in sufficient oxidation, whether by blast or otherwise—hence the desirability of using the purest possible alloy.

As it is silicon which operates to prevent oxide of iron remaining in the bath, it is preferable that whatever is added for this purpose should consist, as far as possible, of silicon, and nothing else.

The combustion of each kilogram of silicon produces 7830 units of heat, i. e., each kilogram of silicon raises the temperature of 100 kilos of molten metal by about 300° Centigrade. White pig iron is not easily refined without ferro-silicon to serve as combustible.

Electric ferro-silicon is practically suitable for the basic process, where it is added as the carbon is being boiled down, and where the metal is poured as rapidly as possible. Therefore, very little carbon being introduced, the operation of decarbonizing the steel is scarcely interfered with, the process is not prolonged, and the fuel saved.

On the contrary, if blast furnace ferro-silicon be added, considerable carbon is introduced and also other impurities at a stage when in this process it is too late to get rid of them by combined boiling, itself involving greater fuel consumption.

Iron.

The operation of remelting cast iron tends always to increase the amount of combined carbon, and to reduce the graphite, thus rendering the iron whiter and harder at every melting.

The presence of silicon, which has greater affinity for iron than carbon, corrects this tendency, because it prevents the iron dissolving the carbon, and thus enables it to retain and even recover the softness due to the presence of a large proportion of graphite.

Generally speaking, the effects are: to render the casting more liquid, and therefore to take the moulds more sharply—to render it sounder—to improve the quality of the iron, largely converting white iron into gray—to render it possible to use cheaper iron and more scrap—and when sufficient in quantity to increase the strength of the casting.

All these effects are due to the contained silicon. Therefore the more silicon there is in the alloy used, the greater is its effect.

Concerning the superiority of the 50 per cent electrolytic over the 10/15 furnace-made ferro-silicon, the results of one of the largest steel casting companies in America are of interest.

In the ordinary run of steel scrap, the practice is to use from 10 to 12 pounds of the silicon, to a ton of the metal charged in the furnace. When the metal is of unusual good quality, this amount can be reduced. That, of course, is left to the judgment of the melter.

The advantage of this high grade silicon over the 10 per cent to 12 per cent is that it is not left in the furnace any length of time. The charge is made by throwing same right into the bath, and the heat is immediately tapped, the time consumed between time of charge of silicon and running of heat, being about ten minutes.

The low grade silicon is banked on the inside of the charging door to thoroughly heat same, then pushed into the bath, even then causing it to chill more or less. It also takes longer

to dissolve, thus causing a large per centage of the silicon to be burnt out. The high grade silicon also acts in the metal like aluminium, causing the metal to be very quiet, especially when the steel scrap is of a very rusty nature.

The electric ferro-silicon alloy can be obtained from Messrs. E. J. Lavino & Co., of Philadelphia, who have arranged to always carry a stock of the metal in this country.

METEORIT

In these days of extended investigations on the properties of alloys it has been found that comparatively very small additions to a metal may give it new and highly desirable properties. While most of the work has been done in connection with the iron and steel industry and an enormous amount of experimental work has been done in this line with all the different rare metals, yet other metals have not been neglected, and various experimenters have tried to attribute to aluminium properties which the pure metal does not possess, without destroying its good characteristic features. In fact, experiments in this line have gone on all the time since the beginning of the aluminium industry.

Several years ago the properties of an alloy of aluminium with magnesium, called magnalium, was much talked of, since it was claimed to be very easily machined. The following information relates to another new alloy, meteorit, which is the invention of Mr. Walter Ruebel, of Germany. We are indebted for this information to Mr. E. May, 74 Beaver Street, New York City, who is interested in introducing this alloy in this country.

Meteorit is essentially aluminium, with an addition of 4 to 7 per cent of phosphorous, but the details of the method of manufacture are kept secret. It seems that meteorit has already found application in various German manufacturing plants, especially shipbuilding works, automobile factories, breweries, manufactories of articles for fire departments, bicycle works, manufactories of electrical apparatus and optical and geometrical instruments.

The following claims are made for meteorit. It makes an excellent casting, milling cutter and planing tools leave a smooth surface. It files clean and clear. It can be cast over and over again without losing its good features. The casting stands a good hammering, whereby it becomes of such density and resistance as to be used for astronomical and mathematical instruments. It is especially suitable for bearing material. It is suitable for rolling and drawing purposes, and can be hammered to the thinnest foil without cracking. A good polish can easily be applied. In general it can be very easily machined. It is stated that it may be easily soldered, and that it receives, without difficulty, an electroplating deposit.

Meteorit has the same low specific gravity as aluminium, viz., 2.6 to 2.8, and the softest meteorit wire (No. 1) has about the same electric conductivity as pure aluminium; namely, 62, against 100 for pure copper, and 88.9 for commercial copper.

Another important property of meteorit is its high resistance against chemical reagents. It is not in the least effected by nitric acid and organic acids, as acetic acid, regardless of its concentration, nor by the fumes of these solutions. It is also stated not to be attracted by neutral salt solutions, even if highly concentrated, nor by ammonia solutions. For rolling purposes meteorit is stated to be very excellent, and sheets have been made of 3 mm. to 0.06 mm. in first-class quality, very hard, as well as soft, the latter being intended for further manufacturing in tubes and for cutting and stamping.

INDUSTRIAL NOTES

Bulletin 147 of the C. & C. Electric Co. gives a list of some users of type MP generators and motors, and some of the principal installations of C. & C. generators and motors. Among them are quite a number of electrochemical and metallurgical plants.

The Vereinigte Fabriken fuer Laboratiums bedarf, of Berlin (formerly Max Kaehler & Martini, and Dr. Peters & Rost), announce that they are soon to open a sole agency at New York City, under the firm name of Laboratory and School Supply Co. The chemical laboratory to be exhibited at St. Louis by the Department of Education of the German Government, and the equipment of the Agricultural Experimental Station exhibited by the Department of Agriculture of the German Government, have been completely furnished by the above-named firm.

A convention of the branch managers, department managers and salesmen of the H. W. Johns-Manville Co., of New York City, was in session from February 15 to February 20. Representatives to the number of about thirty-five from all parts of the country were present. The delegates first met in Hartford, where they were the guests of the Johns-Pratt Co. The object of the convention was to bring all branches into closer touch with each other, and to give opportunity for a general discussion of the various lines of manufacture of the company.

The Lunkenheimer Co., of Cincinnati, makers of superior brass and iron steam specialties, report that owing to the growing demand for their specialties, they have again greatly increased their facilities, and are now in position to guarantee reasonably prompt shipments. They also report, through their foreign branches, an increasing export demand for their specialties and inform us that they will shortly place some new specialties upon the market, which will be contained in a very complete catalogue, to be issued in the course of a few months.

The Goldschmidt Thermit Co. has been incorporated under the laws of the State of New York, with offices at 43 Exchange Place, New York City, Dr. Hans Goldschmidt, of Essen, being president, Mr. E. Stütz vice-president and general manager. While the company is specially interested in the introduction of the thermit process in this country, it intends to conduct business generally in connection with the Chemical & Tin Smelting Works of Th. Goldschmidt, Essen-Ruhr, Germany (founded 1847), and is prepared to handle all products dealt in by the large parent concern. On February 25 Mr. Stütz delivered a lecture on aluminothermics before the Boston Section of the American Chemical Society. The lecture was greatly appreciated, the attendance being over 900.

PERSONAL.

Prof. J. W. Richards, of Lehigh University, is now delivering a series of lectures at Columbia University on iron and steel metallurgy.

Dr. Max von Recklinghausen, who was instrumental in developing the Nernst lamp, and the Cooper-Hewitt lamp in this country, has left for Europe, to establish a Cooper-Hewitt lamp factory abroad.

DIGEST OF U. S. PATENTS

Prior to July, 1902.

Compiled by Byrnes & Townsend,
Patent Lawyers,
National Union Building, Washington, D. C.

Chemicals.

683,000. September 17, 1901. Isaiah L. Roberts, New York City.

Manufactures aluminium hydrate from bauxite by pulverizing the bauxite and heating it in an aqueous solution of caustic alkali until most of the aluminium hydrate is dissolved out. The resulting sodium aluminate solution is filtered and electrolyzed in a cell having a diaphragm consisting of concentric baskets of rubber-covered wire, with their opposing faces covered with cloth and the intermediate space filled in with a stiff paste of finely pulverized anthracite coal, and a 12 to 20 per cent solution of sodium hydrate. A platinum or glass-cemented carbon anode is placed in the diaphragm and the

outer iron vessel constitutes the cathode. The cathode compartment is filled with a weak solution of caustic soda, and the anode compartment with the electrolyte. The aluminium hydrate is deposited on the anode and thence falls to the bottom of the anode compartment. The resulting caustic soda is removed from the cathode compartment and used to dissolve more bauxite and the spent solution from the anode compartment is removed to the cathode compartment.

690,048. December 31, 1901. Lewis Cheesman, Sr., Alxandria, Va.

Treats natural phosphates, e. g., apatites, corprolites, etc., by crushing the rock to powder, mixing with water and nitre cake, and passing electricity through the mixture, using electrodes of platinum. The product is "a residuum of monobasic phosphate, di-basic phosphate, and other compounds." May siphon off the liquid from the cell, evaporate and "add to the solution sufficient sulphuric or nitric acid to render the same slightly acid. In this way the salts soluble in water remain water-soluble."

692,688. February 4, 1902. Maurice Meslans, Paris, France.

An apparatus for producing fluorin by electrolyzing anhydrous hydrofluoric acid containing 25 per cent of fluohydrate or fluorid of potassium. One or more anode compartments consisting of a box of copper having its walls coated with an insulating and inert layer of copper fluorid. The side of the box below the electrolyte consist of superposed, spaced strips of V-section, which maintain the gases separate. A fluorin discharge pipe and a second pipe to assist in expelling the gas open into each anode compartment. A pipe for discharging hydrogen leads from the cathode compartment. The joints in the apparatus contain rubber gaskets. To cool the electrodes, the whole apparatus is immersed in a refrigerating-tank, and a refrigerating liquid may be carried through the hollow anodes by pipe connections. The gas-discharge pipes may comprise coils immersed in a refrigerating liquid, thereby condensing any hydrochloric and returning it to the cell.

695,573. May 20, 1902. Max Buchner, Mannheim, Germany.

Converts wood into dextrine, glucose and alcohol. Reduces the wood to shavings, sawdust or pulp and subjects to the action of a boiling solution of calcium hypochloric and hydrate for an hour or two, then slightly acidifies with sulphuric acid. Again treats at a temperature of 100° C., with water containing 2 per cent of sulphuric and phosphoric acids, until the liquid contains dextrine; then heats in a digester to 150° to 160° C. Neutralizes by introducing calcium or barium carbonate and bleaches the resulting dextroglucose by water charged with sulphurous acid and zinc. To produce alcohol, omits bleaching and passes electricity through the mass in the digester, adding to the cellulose wort, or a little wort containing albuminoid substances such as beet-root or grain. May produce the electric current by placing a zinc-copper couple in the digester. In the apparatus shown the metal digester and a central copper rod projecting from its bottom serve as the cathode, the anodes being a circular row of carbon rods.

700,670. May 20, 1902. Max Buchner, Mannheim, Germany.

Reduces nitro compounds to amins by dissolving or suspending in a suitable bath and electrolyzing with a tin cathode or an indifferent cathode, e. g., of platinum, lead, carbon or nickel, adding stannous chloride to the cathode electrolyte. The tin continuously dissolves from the cathode, effecting the reduction, but is simultaneously redeposited by the current.

Example 1.—Reduction of Nitrobenzene to Anilin.

(a) With a tin cathode.—An electrolytic cell is divided into an anode and a cathode space by means of a suitable and convenient diaphragm. Into the former is poured sulphuric acid of 30 per cent strength, and an anode of indifferent material is arranged therein. The cathode space is preferably provided with a stirring apparatus, and a cooling envelop of any suitable description. Into this cathode-space is introduced a solution of one hundred and fifty parts, by volume, of alcohol, fifty parts, by volume, of fuming hydrochloric acid, and twenty-five parts, by volume, of nitrobenzene or a mixture of twenty-five parts, by volume, of nitrobenzene, with fifty parts, by volume, of fuming hydrochloric acid and fifty parts, by volume, of water. The cathode is an electrode made of tin. When all the parts and materials are in place, the reduction is effected by introducing an electric current of a density preferably of eighteen hundred amperes per square meter for a bath potential of 6.5 volts. When the reaction process is completed, hydrogen begins to escape regularly, and thereby the end of the operation is indicated. The current is now cut off, the colorless cathode-bath is separated from the tin sponge or flakes suspended therein by filtration, and the filtrate is evaporate. The residue is anilin chloride in the form of a colorless crystalline mass, from which the anilin may be isolated by known methods.

(b) With an indifferent cathode in the presence of a tin salt.—An indifferent cathode, consisting, for example, of a net of nickel wire, is arranged in the cathode-space and two parts, by weight, of stannous chloride are added to the cathode-bath, which consists of a mixture of twelve parts, by weight, of nitrobenzene, with seventy-five parts, by volume, of fuming hydrochloric acid and fifty parts, by volume, of water. On introducing into this electrolyte a current having a density of 1000 amperes per square meter for a bath potential of 8.5 volts, metallic tin, is first deposited on the nickel cathode. As soon as the evolution of hydrogen begins, thereby indicating the complete reduction of the nitrobenzene in the cathode bath, further quantities of nitrobenzene, together with the amount of hydrochloric acid necessary to form anilin chloride from the same, may be added to the bath, such further addition being repeated and contained until the solution is enriched with anilin chloride to such an extent that it will directly solidify to a crystalline mass on cooling.

Example 2.—Reduction of Paranitrotoluene to Paratoluidin.

The cathode-space is charged with a mixture of twenty parts, by weight, of paranitrotoluol, one hunderd parts, by volume, of concentrated alcohol (fine spirts), and ten parts, by volume, of fuming hydrochloric acid.

Example 3.—Reduction of Meta-Dinitrobenzene to Meta-Phenylendiamin.

The cathode-space is charged with a mixture of twenty parts, by weight, of meta-dinitrobenzene, two hundred and fifty parts, by volume, of rectified alcohol (fine spirits), and one hundred and fifty parts, by volume of fuming hydrochloric acid.

Example 4.—Reduction of Alpha-Nitronaphthalin to Alpha-Naphthylamin.

The cathode bath consists of a mixture of twenty parts, by weight, of alpha-nitronaphthalin two hundred and seventy parts, by volume, of rectified alcohol (fine spirits), and fifty parts, by volume, of fuming hydrochloric acid.

Example 5.—Reduction of Phenylnitromethane to Benzylamin.

The cathode-space is charged with a mixture of five parts, by weight, of phenylnitromethane, one hundred parts, by volume, of rectified alcohol (fine spirits), and two hundred parts, by volume of fuming hydrochloric acid.

700,672. May 20, 1902. Max Buchner, Manheim, Germany.

Similar to 700,670, but employs copper instead of tin as a reducing agent.

Example 1.—Reduction of Nitrobenzene to Anilin Chloride.

Anode solution, 10 per cent sulphuric acid. Cathode, platinum. Cathode solution: Fuming sulphuric acid, nve hundred parts; water, five hundred parts; nitrobenzene, one hundred and twenty-three parts; cuprous chloride, thirty parts. The nitrobenzene is maintained in suspension by a revolving stirrer, and is replaced as consumed. Current, 1900 amperes per square meter, making cooling desirable. Reduction complete when hydrogen appears.

Example 2. Same as first, but substitutes 20 grams of finely divided copper for the cuprous chloride.

Electrochemical Industry

VOL. II. NEW YORK, APRIL 1, 1904. NO. 4.

Electrochemical Industry

Published on the first of each month by the
ELECTROCHEMICAL PUBLISHING COMPANY,

[*Incorporated.*]

114-118 LIBERTY STREET, NEW YORK.

J. W. RICHARDS, PH. D. .....*President.*
E. F. ROEBER, PH. D. .....*Editor.*

Telephone Call: 7607 Cortlandt.

Subscription Price: $2 per year, postpaid to any part of the world. Single copies 25 cents.

ADVERTISING RATES GIVEN ON APPLICATION.

Copyrighted, 1904, by the Electrochemical Publishing Co.

Entered as Second-Class Matter, June, 1903, at the Post-Office at New York, N. Y., under the Act of Congress, March 3, 1879.

CONTENTS.

Editorial 125
Washington Meeting of the American Electrochemical Society..... 128
German Potash Syndicate..... 128
The Corrosion of Aluminium and its Prevention. By William Roy Mott 128
The Daniell Cell and the Gibbs-Helmholtz Equation. By Henry S. Carhart 130
What Ailed the Dynamo? By C. O. Mailloux..... 131
A Development in Electrolytic Precipitation of Gold and Silver from Cyanide Solutions. By E. M. Hamilton..... 131
Metric System in Mexico and Cuba..... 136
The Relation between Arsenic and Electromotive Force in Copper-Electrolysis. By L. Webster Wickes..... 137
Aluminium, a New Process of Gustave Gin. By P. McN. Bennie.. 138
Preparation and Compression of Pure Gases for Experimental Work. By R. S. Hutton and J. E. Petavel..... 139
Producer Gas and Water Power. By O. Nagel..... 145
The Production of Pure Metals, free from Carbon by the Aluminothermic Method. By Hans Goldschmidt..... 146
Philadelphia Section Meeting, American Electrochemical Society.... 148
Preliminary Program of the Annual Meeting of the Society of Chemical Industry 148
Analysis of Current Electrochemical Patents. By George P. Scholl 149
Synopsis of Articles in Other Journals..... 153
Correspondence: Radioactivity. By Godfrey L. Cabot..... 160
Electrolytic Production of Hydroxides and Oxides. By Fred F. Hunt 160
Current Notes 161
Fireproof Wire. By William H. Easton..... 161
Waterwheel Governors 162
Filterpresses 163
Industrial Notes 164
Digest of United States Patents, Prior to July, 1902. By Byrnes & Townsend 165

WASHINGTON MEETING OF THE AMERICAN ELECTROCHEMICAL SOCIETY.

After winning its spurs by two years of progress unparalleled in the history of any other of our national engineering societies, the increasingly vigorous and active American Electrochemical Society is about to make its debut at our National Capital. To the maiden record of four highly successful general meetings is about to be added another, and probably the most interesting meeting so far held. In addition to the abundance of electrochemical communications offered for reading—papers which by their variety and scope will interest the whole fraternity—the programme bristles with visits to laboratories and museums, excursions in and around "our most beautiful American city," and, *pour comble de la bonté*, a reception of members by the Chief Magistrate of our country. With each member of the American Electrochemical Society, when he reads the programme of the meeting, the question will no longer be "Do I care to attend," but "Can I possibly attend." We predict the most numerously attended and most enjoyable assembly yet held by this unique society.

THE ANATOMY OF THE ATOM.

The late Prof. Rowland, of Johns Hopkins, often used to ask: "Who will be the Kepler of the molecule?" To strive at such honors, was a natural object of ambition on the basis of the old theories of chemistry. For a molecule has generally been considered as a system of atoms which are kept together by mysterious forces, in a similar way as the system of the sun and its planets is held together as a self-contained unit. The development of the electronic hypothesis has brought forward in recent years another and still more fundamental problem of molecular physics. We have witnessed the destruction of the popular faith in the atom's indivisibility which definition and tradition had formerly assigned to it. The atom is now claimed to be itself a complicated system, and its fundamental components are the electrons. But the objection, occasionally raised, that the electron theory tends to degenerate into metaphysics, was troublesome. To overcome such criticisms it was necessary to form a mathematically exact model—in Maxwell's sense—of the structure of the atom. J. J. Thomson, Maxwell's successor as the Cavendish professor of experimental physics at Cambridge and himself one of the very founders and exponents of the electron theory, has performed this task in a most remarkable and most ingenious paper published in the March issue of the Philosophical Magazine and abstracted at length in the Synopsis of our present issue

Thomson starts from a purely mathematical problem; that of the motion of a ring of a given number of negatively electri-

fied particles (or corpuscles, as he calls the electrons) placed inside a uniformly electrified sphere. His first equations are simple enough. He assumes the corpuscles to be arranged at equal angular intervals round the circumference of a circle inside the sphere; the uniform charge of positive electricity within the sphere exacts a radial attraction on each corpuscle, while a repulsion is exerted on it by the other corpuscles. The condition of equilibrium is that this attraction and repulsion are equal. If the ring of corpuscles, instead of being at rest, is rotating with a given angular velocity, the equation for the condition of steady motion is derived from the condition at rest by simple principles of analytical mechanics. Then Thomson proceeds to find the forces acting on a corpuscle when the corpuscles are slightly displaced from their positions of equilibrium, and shows how to determine the frequencies of oscillations. His general formulas become unwieldy like a symphony of Richard Strauss. Yet the tendency which he follows, is clear in all his mathematics; and then, modulating his leading theme, he applies his general equations to calculate the frequencies for systems containing various numbers of corpuscles —two, three, four, five. His mathematics becomes again more and more complicated. For six corpuscles he finds that their arrangement in one ring is necessarily unstable. But peace reigns again, when he puts one more corpuscle into the center; and gradually increasing the number of corpuscles, he finds that if there is to be equilibrium, the corpuscles must arrange themselves in rings; one inside another, the number of corpuscles within a ring gradually decreasing towards the center.

It is, of course, clear that this ring structure of the atom is not exactly the model Thomson is after. What he wants to get at is rather a system of shells instead of rings within the sphere. With the same frankness which distinguished Maxwell in his papers, Thomson now states that on account of the great analytical and geometrical difficulties of the problem of the distribution of the corpuscles in shells instead of rings, he has not as yet succeeded in getting a general mathematical solution for the former case. But nobody who appreciates Thomson's paper at all, will find that its intrinsic value is thereby impaired. It is evident that the same kind of properties will be associated with the shells as with the rings; and since in the latter case Thomson is able to study the problem quantitatively, he is right to do so. Considered simply as a work of mathematical art, Thomson's paper is equal to anything that Maxwell or Boltzmann have produced on similar lines—in the directness by which the problem is attacked, in the beauty and ingenuity of the methods by which it is conquered, and in the inherent complications of the mathematical apparatus involved.

The same objection which has sometimes been raised against Maxwell's and Boltzmann's work in the mechanical theory of heat, may, however, be also made against Thomson's model of the structure of the atom—namely, that too much ingenuity is spent for the purpose of arriving at facts which are well known. It is true that Thomson brings out no new chemical facts. His paper is like Sophocles' Œdipus—one knows all the results in advance; and, as in that overwhelming Greek drama, so in Thomson's paper, the whole interest centers in the way in which the results which will and must come, are reached. Thomson shows that if an atom consists of a number of negatively charged corpuscles moving about in a sphere of uniform positive electrification, then the corpuscles must be assumed to form a series of concentric shells, and then Thomson goes on to show that the properties conferred on the atom by this shell structure are analogous in many respects to those possessed by the chemical elements, and that in particular the properties of the atom will depend upon its atomic weight (which is proportional to the number of corpuscles in it) in a way very analogous to that expressed by the periodic law. He shows why the elements arrange themselves into the groups of the periodic system. He develops the main laws of the line spectra of the series of elements. He explains the variation of valence and the change from the electropositive to the electronegative character of the elements, when one passes from the left to the right in a horizontal row of Mendeléef's table. He finally gives a new conception of the radioactive atom. All these results follow in such a simple and natural way with absolute consequence from his shell structure of the atom, that the whole scheme is one of the most wonderful achievements ever attained in theoretical physics. For this reason we need not apologize for the unusual length of the extract which we give in our Synopsis from this part of Thomson's paper.

According to Kirchhoff, the object of theoretical physics is to describe the facts in as complete and as brief a manner as possible. A statement of "laws of Nature"—either with or without the aid of mathematics or of mechanical models or analogies—is nothing but a brief description of a group of facts. Of course, such a law can become wider than the group of facts which it was originally intended to describe, and then we can use the law to derive from it new results and to predict facts which have not yet been ascertained by experiment. But only by afterwards establishing experimentally these theoretical results to be facts, we prove the law to be correct. Thomson's model of the structure of the atom is the first scheme ever devised for a consistent description of the facts of the periodic system of the chemical elements. It is a surprisingly complete and brief description of these facts, if we once accept the shell structure of the atom. But the original conception of the atom as a series of concentric shells of corpuscles within a sphere of uniform positive electrification seems highly artificial, not so much on account of the shells of corpuscles which are a comparatively simple conception, but on account of the sphere of uniform positive electrification, which, while mathematically sharply defined, will appear somewhat mysterious to the average man. We should not forget, however, that it was from such models, which were apparently very artificial, that Maxwell started in the evolution of his electromagnetic theory.

ELECTROLYTIC PRECIPITATION OF GOLD.

In this issue we publish a very interesting paper by Mr. Hamilton on the modifications which the Siemens & Halske process for the electrolytic precipitation of gold, as originally operated in South Africa, has afterwards undergone in this country and in Mexico. Nothing that is essential has been changed in the chemistry of the process, the modifications relating

rather to changes in details. But, as is often the case in industrial chemistry and metallurgy, such apparently small changes may be of the very greatest practical importance, and may often decide the commercial future of a process. The first modification of the original Siemens & Halske process consists in the substitution of a lead peroxide anode for the iron anode. The result is that the anode is thus rendered practically indestructible, that no such compounds are formed as Prussian blue with iron anodes, and that the anode is no longer covered with canvas or the like; and what is most important, the anode, being indestructible, no longer limits the value of the current density which can be used.

The second modification relates to the cathode. The gold is no longer plated upon the cathode but is deposited in form of slime, which drops to the bottom. The method of cleaning out is simple. The cathode plates, which are now made from tin, are continually in the tanks and a good joint between the cathodes and outside conductors is assured. This evidently renders the whole method of handling much easier. The important question is now what is the best current density to be used. The author shows that it depends on three factors—the percentage of gold in solution, the rate of flow of the solution, and the area of the electrodes. He gives some very interesting data on these points, and also gives an account of some experiments which he has made on certain other questions which are not only of practical importance, but of great theoretical interest. We intend to refer to the same again in a later issue.

THE POWER PROBLEM.

In order to carry on any manufacturing process with a profit, it is necessary that the cost of raw materials plus the cost of operation plus the cost of shipping of the raw materials to the place of operation, and of the manufactured product to the place of consumption is smaller than the price which one finally gets. In electrochemical and electrometallurgical industries the cost of power is one of the main items and often the most important item of the cost of operation. But cheap power is not the only condition of the financial success of electrochemical industries; the source of cheap power must be at the right place to avoid large expenses for freight. No general rules can be laid down concerning the place where the cheap power should be available in order to make the cost of shipping a minimum. For instance, for manufacturing nitrates from the nitrogen of the air there would be no expenses for the raw material nor for its shipment; hence a source of cheap power should be chosen near the place where the nitrates are to be sold. On the other hand, in the reduction of metals from their ores, the freight expenses would be smallest, if the process is carried out near the mine, provided cheap power is there available. In general, we may say that the prospects for electrochemical and electrometallurgical industries are most promising wherever there are cheap raw materials and cheap power, provided the product is valuable enough to also pay for the shipment of the products to the market place. In this respect the United States is greatly favored by Nature, as is indicated by some statistical data, given in 1899 in a German Electrochemical Society paper of Prof. W. Borchers.

According to Borchers, the power developed for electrochemical and electrometallurgical industries in this country at that date were 86,350 hp., or 20 per cent of the total 421,220 hp. of all the electrochemical plants of the world. On the other hand, the value of the products which could be made per year by utilizing the 86,350 hp. to their full extent, was $97,500,000, or 67 per cent of the corresponding value for the whole world, which is $146,500,000. While these figures, considered as absolute values, are now somewhat stale, they emphasize extremely well the fact which we wish to bring out. It is the discrepancy between 20 per cent—the proportion of power developed for electrochemical purposes in the United States to the corresponding value in the world—and 67 per cent—the analogous proportion for the value of the yearly products. This discrepancy is, of course, explained by the fact that this country has an abundance of valuable ores from which highly valuable metals may be obtained.

With regard to the availability of raw materials for the manufacture of valuable products, the United States is thus immensely favored by Nature in comparison with other countries, and thus the principal condition for the successful development of electrochemical and electrometallurgical industries is fulfilled in this country to a high degree. Under these circumstances it is the power problem which is now attracting special attention. Steam power has often been considered to be too expensive for electrochemical purposes; but that steam is not entirely out of the race is shown, to mention only one instance, by a large electrolytic alkali plant in Michigan, where coal is cheap. For the central station engineer, electrochemical plants should be very attractive as customers, since there is probably no electric plant which has such a uniform load during day and night, and during the whole year, as most electrochemical and electrometallurgical works. The introduction of the steam turbine on a commercial scale also seems to improve the prospects for steam power. Water power developments have been most intimately connected with certain electrochemical industries in the past, and there is no reason why there should be a change in the future. Niagara Falls is not only the largest water-power plant, but also the most prominent center of electrochemical industries in the world. In this country it is most fortunate that several of the largest water-powers are just where they are wanted, that is, not at out-of-the-way spots, but at places which are conveniently situated for shipping. Most recently, gas engines are pushing vigorously to the front, and some data given by Dr. Nagel in an article in this issue will prove interesting reading. It is especially the utilization of the waste gases from blast furnaces which should have a great future. Their utilization for operating gas engines, coupled to electric generators for electric lighting and for general power purposes, is sure to come, and the operation of electric furnaces for making special steels in conjunction with our present blast furnaces seems a logical development. Whatever is best to use, whether water or gas or steam power, depends, of course, on the conditions of each special case. Such most conveniently located water powers, like Niagara, will, of course, continue to attract in future electrochemical industries. On the other hand, extended coal centers, like Pennsylvania, will be very attractive for gas-power developments; and in our large blast furnace plants the furnace gases will no longer be wasted.

WASHINGTON MEETING OF THE AMERICAN ELECTROCHEMICAL SOCIETY.

The fifth general meeting of the American Electrochemical Society will be held in Washington, D. C., on Thursday, Friday and Saturday, April 7th, 8th and 9th. This will be at the same time the third annual meeting and the election of new officers will be announced.

The meeting will be held at the Columbian University, corner Fifteenth and H Streets, N. W. In the mornings of the three days, meetings will be held devoted to the reading and discussion of papers, and to the transaction of the business of the Society, Thursday and Friday afternoons will be devoted to visits to scientific laboratories, government institutions and various points of interest in and about Washington; on Thursday evening, the presidential address will be delivered and will be followed by a complimentary smoker, while Friday evening a subscription banquet will be held at the Shoreham, corner Fifteenth and H Streets, N. W., opposite the Columbian University. The Shoreham will also be the hotel headquarters during the convention.

The chairman of the local committee is Col. Samuel Reber, the Secretary, Mr. C. P. Townsend. The finance committee consists of Col. Samuel Reber as chairman and Messrs. C. P. Townsend, T. A. Witherspoon, H. H. Seabrook, W. D. Young; the entertainment committee of Dr. N. M. Hopkins as chairman, and Dr. E. A. Byrnes and Mr. W. O. Snelling; the executive committee, Dr. H. W. Wiley as chairman, and Dr. M. G. Lloyd, Mr. A. B. Marvin, Mr. Henry J. Lucke and Dr. Edward Keller

The following papers will be read and discussed at the meeting of Thursday, April 7:

"Standard Cells," Dr. F. A. Wolff; "The Preparation of Materials for Clark and Weston Standard Cells," Dr. H. S. Carhart and Dr. G. A. Hulett; "Single Potentials of the Halogen Elements," W. R. Mott; "The Composition and Resolution of Voltages," Dr. J. W. Richards; "Molecular Conductivity," C. J. Reed; "Remarks on Prof. Richards' Theory of Heat of Neutralization," Gustaf M. Westman; "The Energy of Ions," Dr. L. A. Parsons; "The Aluminium Electrolytic Condenser," C. I. Zimmerman.

For the Friday meeting the following papers are announced:

"Electrolytic Iron," Prof. C. F. Burgess and Carl Hambuechen; "The Economic Balance in Electrolytic Copper Refining," Lawrence Addicks; "A New Electrolytic Separation of Gold and Silver," Herman Poole; "Observations on the Preparation of Electrolytic White Lead," C. F. Carrier, Jr.; "The Relation Between the Cost of Salt and the Cost of Power at a Given Locality, and the Resulting Cost of Elctrical Bleaching Liquor Produced," Dr. W. H. Walker; "A Relative Decimal Index for Electrochemical Interests," Adolph L. Voege; "Notes on the Industrial Electrolysis of Water," W. S. Landis.

At the Saturday meeting the following papers will be presented:

"A Contribution to the Study of the Electric Arc," Dr. William S. Weedom; "Electric Smelting Experiments for the Manufacture of Ferro-Nickel from Pyrrhotite," Ernst A. Sjöstedt; "Some Experiences in Copper Precipitation," Hermann Poole; "The Relation of the Alternating Current to Osmotic Pressure," W. H. Davis; "Some Phenomena Observed in Connection with the Use of a Copper Voltameter," Isaac Adams and Barry MacNutt.

GERMAN POTASH SYNDICATE.

A recent consular report (dated January 21) from United States Consul-General Mason, of Berlin, Germany, reads as follows:

During the past three days the representatives of the associated potash mineral interests have been in session at Berlin trying—but thus far without success—to agree upon a plan by which their hitherto iron-girt and inflexible working and sale syndicate can be prolonged beyond the close of the present year. As an illustration of the ethics of syndicate management under natural conditions, which constitute a practical monopoly of an important group of products, the potash trust of Germany, known as the "Verkaufs-Syndikat der Kaliwerke," possesses a unique interest.

As is well known, Germany possesses the only known workable deposit of potash minerals in the world.

Under the management of a syndicate, or combine, the prices of all potash minerals and refined salts were fixed for the home market and for export, and the rate of production so regulated that the supply should never overload and depress the market. So matters went on peaceably for many years; a large and constant demand for potash fertilizers was developed in the United States, which took regularly something more than half of the entire exported supply. These potash fertilizers are used largely in the United States in combination with the mineral phosphates of the Carolinas and Florida, the production and sale of which likewise fell, in the course of years, largely into the hands of a powerful and ably managed company, or syndicate, which has its headquarters in the capital of one of the Southern States. This company finally grew weary of the limited supply of potash materials and the high prices charged for them by the German syndicate, and during the spring of 1902 sent some of its leading managers, with a mining engineer, to Germany, where they undertook openly and above board to secure by purchase some of the more important independent potash mines outside the syndicate, from which to obtain, as they hoped, a direcct and permanent supply under their own control.

The sensation that was caused by this American movement to break into the sacred precincts of the German potash monopoly will long be remembered. They failed, for the time being, to secure any important mining property, although they succeeded later in purchasing one or two producing mines, which they are now operating for the production of refined potash salts. But the two notable results of the American negotiations at that time were that the Southern Fertilizer Company secured a favorable contract with the Stassfurt Syndicate for the delivery of an increased annual supply of potash minerals and salts for export to the United States, and, secondly, the syndicate itself was alarmed and admitted as members a number of outside mining companies, which it had prevously refused to accept. This raised the whole number of firms and companies included in the syndicate to 27, and, of course, greatly increased its productive capacity. Many of the new members had their mines fully developed and equipped, and were eager to begin operations on a large scale. The result was that the enlarged syndicate started out with great activity and high hopes during the spring of 1902, but soon found its rate of production so far beyond the capacity of the market at syndicate prices that by the middle of July there was a glut of unsold material, which necessitated an abrupt contraction of the general output.

The proposition is to formulate and adopt a new and broader contract, which shall continue five years from the 1st of January, 1905. Whether this can best be done under a cartel similar to the agreement now in force or as a stock company with limited liability is a point upon which some of the members sharply disagree.

There is, of course, a definite limit to the distance to which minerals worth only $2.54 to $3.45 per ton can be profitably transported, and it is probable that the future development of the potash industry will be largely in the direction of a greatly increased production of concentrated potash salts and the elimination thereby of the large percentage of dross or waste that now encumbers traffic in the crude minerals.

The erection of the Union Engineering Building is now assured. Mr. Andrew Carnegie has donated $1,500,000 for the building, while the for societies will acquire the land.

THE CORROSION OF ALUMINIUM AND ITS PREVENTION.

By William Roy Mott.

A study of aluminium and its properties is of considerable importance. The commercial value of aluminium follows, as is well known, mainly from its workability, strength, lightness, lustre, electrical conductivity, permanence and cheapness. Many irregular data are extant upon its permanence and corrosion. The lightness of aluminium greatly commends its use for utensils in military camps; extensive tests have been made by the French military experts in this direction. Many articles of aluminium in domestic use are subjected to the corrosive action of the sodium chloride in the preparation of foods and in contact with the perspiration of the human hand. Many striking cases of corrosion of this kind are met with. Burgess and Hambuechen have given an instance of this kind of corrosion, in their paper upon aluminium, published in the Electrochemical Industry, January, 1903. In this paper the formation of a film over aluminium was carefully discussed from several viewpoints. As was pointed out, a film forms over an aluminium anode in certain solutions, such as sodium acid phosphate. This film has been found by the author to greatly decrease the rate of corrosion of aluminium. It is experiments upon this special protective action of this film that the author proposes to detail here.

This film is many times thicker and *chemically different* from the ordinary film that forms upon aluminium in air.

Aluminium on which this film has been formed shows decidedly less chemical action. Aluminium plates formed at 125 volts were tested as to rate of action (table I.) with normal hydrochloric acid (plate I.) potassium hydroxide and normal sulphuric acid (plate II.). The aluminium plates, of nearly the same size, were acted upon by the same reagents under like conditions. The action of hydrochloric acid upon the untarnished plate is one hundred times faster than upon the plate on which a film is formed; but after one hour the action

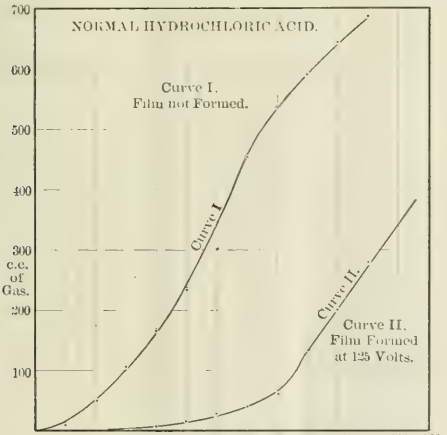


PLATE I. ACTION OF HYDROCHLORIC ACID

on the unformed plate is only six times faster than on the formed plate. After two hours the rate of action is practically the same on both.

Normal potassium hydroxide acted with nearly equal rate on both plates, and the corrosion was nearly uniform. This was to be expected, since potassium hydroxide readily dissolves the oxide and hydroxide. The corrosion of the formed plate by hydrochloric acid is worthy of note. It starts in spots, seems to creep under the film, and causes it to peel off in plates. At these exposed places the action is vigorous. On taking the plates out, portions protected by the film remained uneaten.

The action with sulphuric acid was one thousand times slower than with hydrochloric acid or potassium hydroxide. Here the metal protected by the film gave off less gas than the other, especially within the first ten hours. The reason for the slow action of the sulphuric acid, is no doubt due to the fact that it is one of the agents which can be used to form the film. Quantitative measurements on disodium hydrogen phosphate showed that this acted at nearly the same rate as the sulphuric acid.

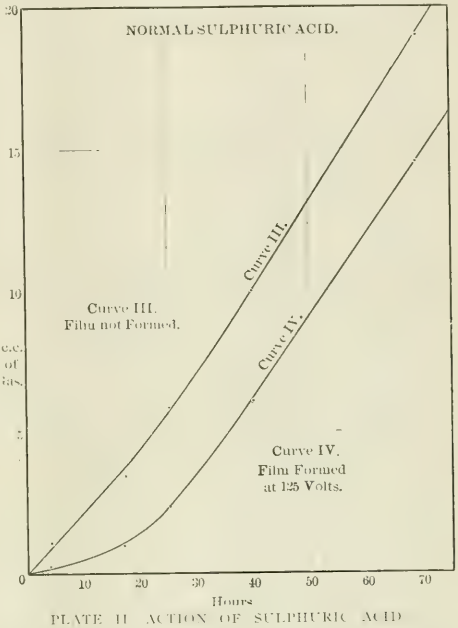


PLATE II. ACTION OF SULPHURIC ACID

Table I.—Rate of Chemical Action with the Formed and Not Formed Aluminium Plates.[1]

	Normal Hydrochloric Acid [5]		Normal Sodium Hydroxide [4]			Normal Sulphuric Acid [5]		
Time in Minutes.	Number 1.[2]	Number 2.[3]	Time in Minutes	Number 3.[2]	Number 4.[3]	Time in Hours.	Number 5.[2]	Number 6.[3]
10	9.0	.00	10	10	8	4	1.0	0.1
20	50	0.10	20	10	..	17	3.4	1.0
30	110	2.0	40	22	24	25	5.8	2.4
40	170	5.0	60	26	27	40	10.0	6.0
50	230	9.2	240	40	41	69	19.0	14.5
60	300	18						
70	450	32						
80	540	55						
90	595	135						
100	650	200						
110	690	280						

[1] Area of plates was, approximately, ten square centimeters.
[2] 1, 3 and 5 not touched and film not formed.
[3] 2, 4 and 6 formed at 125 volts in disodium hydrogen phosphate solution at room temperature.
[4] These readings of cubic centimeters represent only the quantity of gas given off in ten minutes.
[5] These readings represent the total gas in cubic centimeters given off in that time.

Aluminium strips (area 10 square centimeters) were formed using direct current at pressures, as indicated in table II. The strips, formed with alternating current, were sub-

jected to the pressure indicated in table III. for five minutes each. The maximum pressure of an alternating current is, of course, considerably greater than the effective pressure which the voltmeter measured.

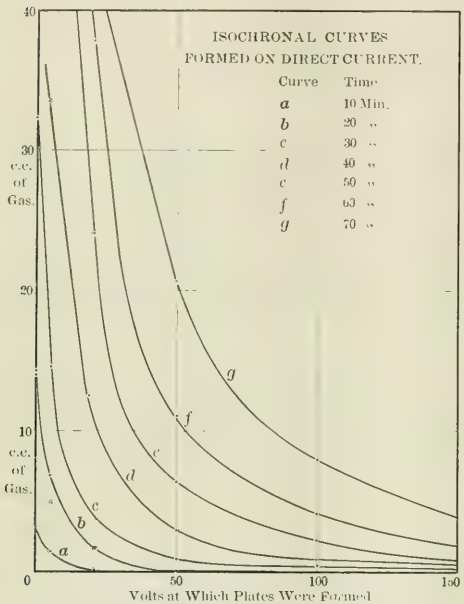


PLATE III.—ISOCHRONAL CURVES.

Table II.—Aluminium Plates Formed with Direct-Current.[1]

Volts. Min.	Not Touched Gas. Cu. Cen.	Washed[2] Gas. Cu. Cen.	1 Volt. Gas. Cu. Cen.	5 Volts. Gas. Cu. Cen.	10 Volts. Gas Cu. Cen.	20 Volts. Gas. Cu. Cen.	50 Volts. Gas. Cu. Cen.	100 Volts Gas. Cu. Cen.
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	3.5	2.9	0.4	1.5	0.1	0.1	0.1	0.00
30	14.2	14.0	21.0	5.0	1.8	1.8	1.0	0.1
40	32.0	30.5	44.0	15.4	5.2	5.1	3.0	0.7
50	54	52	66.0	33.1	12.5	12	6.3	2.1
60	83	80	96.0	57	28	23	11.4	4.0
70	111	106	127	85	44	38	20.5	8.0

[1]Area of the aluminium strips was ten square centimeters.
[2]Disodium hydrogen phosphate.

After being washed and allowed to dry, the strips were placed in a eudiometer with normal hydrochloric acid solution. The gas given off was read every ten minutes. These readings, taken at equal intervals, are plotted in the isochronal curves (plate III., direct current) with total cubic centimeters of gas as ordinates and as abscissæ the volts at which the aluminium plates were formed.

These curves show that the protective action is directly proportional to the voltage at which the plate is formed. As the time from the start increases, the rate of reaction increases. All the plates gave very little gas during the first ten minutes. The plates formed at lower voltages then quickly accelerated their rate of reaction, and those formed at higher voltage lagged behind giving off gas very slowly.

The very decided decrease in the corrosion of aluminium plates b hydrochloric acid would be still more pronounced in corrosion by sodium chloride. The auther is of the opinion that utensils such as aluminium jars, cups, combs, etc., all kinds of aluminium handles could be coated with this film to advantage. Another field of importance is the treatment of electric lines of aluminium that are exposed along the sea coasts to the corrosive action of sodium chloride. Special treatment of the film has been found by the author to still further decrease the corrosive action of the chlorides upon aluminium. This article will be followed by others which will detail experiments upon the thickness, composition, mode of formation, mechanical and electrical properties of this film.

Table III.—Aluminium Plates Formed with the Alternating Current.[1]

Volts. Min	10 Gas. Cubic Cent.	20 Gas. Cubic Cent.	100 Gas. Cubic Cent.	150 Gas. Cubic Cent.
0	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00
20	0.5	0.2	0.1	0.1
30	4.5	2.0	1.0	0.4
40	14.5	6.0	3.4	1.0
50	35.0	15.5	8.5	1.6
60	69	35	21.7	2.2
70	107	65	50	3.2
80	160	109	99	4.0

[1]Area of the aluminium strips was ten square centimeters.

In conclusion, it is my pleasure to thank Prof. Burgess ar l Dr. Patten most heartily for favors and privileges extended me in carrying out this line of experiments. And, finally, I wish to express my lasting obligation to Professor Louis Kahlenberg for laboratory facilities, for his continued interest in my work and for the counsel and suggestions given me.

Chemical Laboratories of the University of Wisconsin.

THE DANIELL CELL AND THE GIBBS-HELMHOLTZ EQUATION.

By Prof. Henry S. Carhart.

Mr. Woolsey McA. Johnson's paper in the March number of Electrochemical Industry contains an ancient error which should be given a decent burial. It is not an error of Mr. Johnson, but it is one that has been repeated in almost every paper and book in which the experimental confirmation of the Gibbs-Helmholtz equation has been the subject of comment and illustration since the appearance of Jahn's celebrated investigation relating to the Helmholtz principle. (Wiedemann's Annalen, Vol. XXVIII., pp. 21 and 491, 1896). I refer to the case of the Daniell cell as a confirmation of the Gibbs-Helmholtz principle. This principle has been established beyond question, but not by the Daniell cell. The data obtained from the Daniell cell are opposed to the conclusions of the Gibbs-Helmholtz theory. I do not doubt that if we had absolutely correct data for any specific solutions of the Daniell cell, they would be in harmony with the Helmholtz principle.

Mr. Johnson has given correctly the calories obtained by Jahn measured electrically in the one case and thermally in the other, with solutions consisting of $CuSO_4 + H_2O$, and $ZnSO_4 + 100\ H_2O$. For a half gram molecule they are 25.263 and 25.055 calories respectively. The electrical energy given out by the cell was therefore 0.208 calory greater than the heat of the reactions. The cell should then have a positive temperature coefficient. Now Jahn did not determine this temperature coefficient, but assumed a value given by Gockel. But Gockel's solutions were not the same as those of Jahn.

With concentrated copper sulpnate solution the temperature coefficient of the Daniell cell decreases with the concentration of the zinc sulphate solution. Helmholtz says in his celebrated paper (*Sitz. der Wiss. Akad. zu Berlin* 1—1882, p. 24) that the temperature coefficient of the Daniell cell becomes zero with a

concentrated solution of copper sulphate when the specific gravity of the zinc sulphate solution is about 1.04. With a still weaker solution the coefficient may become positive. I have not been able to confirm Helmholtz's conclusion because of the interferences introduced by oxidation, especially when the cell is heated. No doubt remains, however, that with the solutions used by Gockel, the temperature coefficient is negative, while Jahn's data require that it should be positive.

The other six voltaic combinations investigated by Jahn confirm the Helmholtz principle in unmistakable terms; the difference between the electrical energy and the thermal energy of the Daniell cell is too small to be reliable as an indication either way. It would therefore be much wiser in quoting Jahn's results, to take some other case than that of the Daniell cell—a case where the results are so large as to be unmistakable.

WHAT AILED THE DYNAMO?

By C. O. Mailloux.

The caption "What Ailed the Dynamo" in the March number of Electrochemical Industry (page 86) attracted my attention, and I read the article with feelings of increasing surprise, amusement and also, I may confess, of impatience at the two "experts," so-called, of the electrical manufacturing company, one of whom went home "*still thinking*," while No. 2 was preparing his "tricks," to "test the insulation." Two experts, indeed! Two dromios, in a comedy of errors! Shades of John Hopkinson! That two amateurs—aye, two tyros—should have occupied the center of the stage in a two month's production of a farce suggesting, in name only, "Much Ado About Nothing," a serious drama of the immortal bard, must surely make Joseph Jefferson and Francis Wilson feel sad; they should have become "electrical experts" in order to reach the most exalted plane as comedians.

Of course, one does not need to be an expert, to see that if expert No. 1 had been able to "think" at all, if he had had any knowledge worth mentioning on the subject of armature reaction, it would not have taken him much time to diagnose this "ailment" as a plain, common and altogether natural (physiological, forsooth) case of armature reaction reaching or attaining an excessive degree which is incompatible with good commutation, as the result of a weakened magnetic field. Surely it would seem as if everybody at all familiar with the the theory of the dynamo, ought to know as a fact and should understand the reason that the limiting load in amperes which a dynamo can carry without objectionable or injurious sparking—in other words, the limit of good commutation—decreases greatly as the magnetic field is weakened. It is, of course, possible by means of special designs and windings—notably the so-called "Sayers" winding, to obtain sparkless commutation with the full load current at very low e. m. f's., but it is not possible to obtain it with a machine of the usual type and design, when the magnetic field is reduced in the ratio of 80 to 120 (or two-thirds of its normal "strength"), unless the magnetic circuit has new mysterious properties in the particular case. Assuredly, the designing department of that large electrical manufacturing concern must have known better, and could have done a little thinking, even if neither of the alleged experts could.

The expedient finally adopted, namely, to maintain the magnetic field at full strength, as nearly as possible and to reduce the engine speed, is the correct remedy, as experienced electricians and dynamo-room attendants know very well. When the reduction desired in the e. m. f. is only relatively slight, it can usually be effected by cutting out the field shunt rheostat, so as to still obtain the full exciting current with a lower potential difference at the terminals of the shunt winding, and then reducing the rotative speed of the armature. When the reduction desired exceeds a certain limit, as in the case described by Mr. Browne, the potential difference available at the terminals of the shunt winding would no longer suffice, even with all the resistance cut out at the rheostat, to produce the required full exciting current in the shunt coils; and it therefore becomes necessary, and is the most evident thing to do, to cut down the shunt resistance by reconnecting the coils, so as to have two sets in multiple, making the resistance of each set one-half as great as that of the whole shunt, and consequently making it possible to obtain the full exciting current with half the potential difference required for the whole shunt. The total exciting current will, of course, be twice as great, there being now two half windings in multiple.

The method suggested by Mr. Browne, to prevent reversal of the magnetic field, is obviously a proper one. It answers the purpose quite as well, however, to slightly reduce the load in amperes, before operating the circuit breaker, and it subjects the machinery to less strain. The general rule followed in all plants where several units are coupled together, would apply perfectly here, if we treat the vats as a "unit" having an e. m. f. of its own. The rule in *disconnecting* is simply to watch the ampere meter while manipulating the field resistance, so as to reduce the e. m. f., and, of course, the load (amperes) given out by the armature. When the load has fallen off to the proper amount, usually from 5 to 20 per cent of full load, then the circuit is opened either by the circuit-breaker or the main switch. In starting, the field is usually brought to full strength and the e. m. f. is allowed to attain its full value before the main switch is closed. In a case such as described by Mr. Browne, it would, perhaps, be better to excite the field only enough to give an e. m. f. sufficient to overcome any possible e. m. f. of "polarization" in the vats, say 40 or 50 volts; then close the main switch and "build up" the e. m. f. and the load until the desired current is shown by the ampere meter.

A DEVELOPMENT IN ELECTROLYTIC PRECIPITATION OF GOLD AND SILVER FROM CYANIDE SOLUTIONS.*

By E. M. Hamilton.

This paper is not designed to reopen the old discussion on the respective merits of the electrolytic and zinc methods of precipitation, but merely to bring before the Society certain modifications in the Siemens & Halske process as originally worked in South Africa, which have been developed by Messrs. Charles Butters & Co., Ltd., in Mexico and the United States of America.

I think it was in 1899 that Mr. H. T. Durant was first engaged in working out these modifications at the Minas Prietas Reduction works of Messrs. Charles Butters & Co., in the State of Sonora, Mexico. He had made a start in this direction shortly before leaving South Africa, by experimenting with peroxidised lead anodes, but it was in Minas Prietas that most of the work was done.

The plant at Minas Prietas is of modern design, much after the style of the South African cyanide plants, with sands and slimes departments, and the method of slimes treatment is that usually adopted in plants under the control of Mr. Charles Butters, viz., the use of a single tank for the treatment of one charge, instead of transferring the charge from tank to tank, and the use of mechanical stirrers in addition to centrifugal pumps for agitation purposes. The capacity is about 9,000 tons a month, of which about 40 per cent would be slimes and the rest sands. The tailings being treated at the time referred to

*In our February issue we gave an extended review of the early developments of electrolytic precipitation of gold by the Siemens & Halske process, in South Africa, and notably of the work of Mr. Chas. Butters and his associates. Our former article may be read as an introduction to the above paper of Mr. Hamilton, which was recently presented to the Chemical, Metallurgical and Mining Society of South Africa. Dealing with recent developments and modifications of the Siemens & Halske process in America, Mr. Hamilton's paper gives important information, supplementary to the article in our February issue.—Ed.

were accumulated in dams after having been handled by the pan-amalgamation process, and for every dwt. of gold would carry, roughly, about 1 ounce per ton of silver, and also a variable amount of copper derived from the pan treatment.

When I arrived in Minas Prietas in July, 1900, I found the following precipitation plant in operation: Six boxes, each 30 feet long, 10 feet wide and 5 feet deep (with the bottom inclined to one side), and divided into twelve compartments, each of which contained 18 anodes and 17 cathodes. The boxes were placed in two rows of three, and the solution passed through two boxes in succession before reaching the storage tanks. Four of the boxes were used for slime solution, and the other two for sand solution; the current was supplied by two Siemens & Halske dynamos, each having a capacity of 250 amperes and 30 volts, and the current density was from 0.2 to 0.25 ampere per square foot of anode surface.

Before going into the details of working it will be well for me to state briefly the chief points of difference between this method and the Siemens & Halske process as originally worked.

1. The anode, instead of being made of iron, is composed of sheet lead coated with peroxide, and is not covered with canvas or enclosed in any way.

2. The metal precipitated is not plated on the cathode, but is deposited thereon in the form of a fine slime, which falls to the bottom of the box, and is cleaned up and dealt with exactly in the same way as the similar product from the zinc process. Now, as to the method of working.

Anodes.—The anodes above mentioned are sheets of lead about 3-16 inch thick, with a lead lug soldered on the corner of each, and a strip of wood along the top to strengthen it, and by which to suspend it in the box. It is coated with peroxide by being placed in a bath of permanganate of potash and connected with the positive pole of the dynamo for a given time.

After repeated trials under different conditions we find the following to be the most satisfactory way of making the anodes which we have as yet tried: The sheets of lead are received, cut to the desired size, then one corner of each sheet is scraped clean on both sides, and a cylindrical lug about ½ inch in diameter, and 4 inches long (or a pair of such lugs) is cast onto the plate. This is done by means of a split iron mould with handles, somewhat after the style of the old-fashioned bullet mould, which is clasped and held on the corner while the molten metal is poured in from the top. It has been found advisable to add a small quantity of tin-solder to the lead used for the casting, so that it may have a slightly lower melting point than the lead plate, sufficiently so to avoid fusing the latter though, while at the same time being hot enough to make good junction at the surfaces of contact. The next thing done is the placing of the wooden support; we now put this on in one piece, instead of in two strips, as formerly. Lengths of wood about 1 inch square are grooved out of one of their sides to a depth of about ¾ inch, and 3-16 inch wide. These are then cut into short lengths the width of the plate, and the top edge of the latter placed in the groove, where it is secured by four or five wooden pegs driven through the wooden strip and lead sheet, and holding the two firmly together. The plate is now ready to be peroxidised. At Minas Prietas this is done in a special box, which holds only three plates at a time, but in the case of a new installation it would probably be found more convenient to fix up one of the working boxes for this purpose and do a large number at a time.

We have found that to get the best results the plate should be scratch-brushed immediately before being placed in the bath, so as to give a clean, metallic surface. The solution should be not less than 1 per cent of permanganate of potash in water, and should be maintained at this strength by frequent additions of the permanganate as the solution grows weaker; tests on it being made at intervals by titration with ferrous sulphate. The plates, when placed in the bath, are at once connected with the positive pole of a dynamo, the cathodes of the cell being formed of similar lead plates, which, of course, remain there throughout. The current density used for the operation is 1 ampere per square foot of anode surface, and the minimum time of treament is one hour. Anodes peroxidised in this way have been in use for the last ten or twelve months, and at the present time have as good a surface as on the day they were first placed in the box.

Cathodes.—At the outset the cathodes used were lead foil, cut into strips and hung on wires, as in South Africa. These were removed every day or two, and the deposit washed off with brushes under a stream of water, the cathodes being then replaced in the box. A large proportion of the deposited metal would also drop off the lead foil and fall to the bottom of the box, from which it was periodically cleaned up.

It will readily be seen that a thin, lead-foil cathode cut into strips would not long stand such an amount of handling as was involved in this method of cleaning, and very shortly after my arrival my attention was called to finding some form of cathode more suitable to our purpose. After experimenting with various metals, we have at length settled on a cathode of tin plate, which, up to the present, seems to work very satisfactorily. The material is simply good quality commercial tinplate, and each cathode has a strip of iron about ¾ inch wide and ⅛ inch thick riveted along the top edge, to support it in the box. The wire connecting it with the electrical circuit is soldered onto the surface of the plate, the other end being also soldered onto the copper tape which supplies the current.

The cleaning is done in the box by means of a kind of double squeeze, which, being slowly passed down the surface of the plate from above, wipes down both sides at the same time, and leaves the precipitate settled on the bottom of the box; each cathode is cleaned thus every day or two, as may be found necessary, the flow of solution being, of course, closed off during the operation.

The advantages of a tinplate as a cathode over the lead foil are as follows:

1. It is practically indestructible.

2. It can be cleaned down without being removed from the box.

3. It affords a means of perfect electrical connection with the copper leads, which was impossible when the cathode was a sheet of lead foil bent over a piece of iron wire. Anyone who has worked with the latter will know how very unsatisfactory used to be the connection and the consequent distribution of current.

For the periodical clean-up we have at Prietas to remove four or five anodes and cathodes in the center of each compartment but our new boxes at Virginia City Works, Nevada, U. S. A., are built with spitzkasten bottoms, so that neither anodes nor cathodes need ever be removed from their places, all that is necessary when clean-up comes round being to open a decanting pipe and run off the clear liquor, and then open a valve in the point of the bottom and run the precipitate wherever it may be needed, afterwards flushing out the inside of the box by means of a hose and a little clean water.

The deposition of the metal as a slime instead of a plating is effected by increasing the current density till it is in excess of its proper ratio to the amount of metal in solution and decomposition of water occurs, causing deposition of hydrogen on the cathode simultaneously with the metal.

The advantages of the foregoing modifications over the older method of work, as originally practiced in the Witwatersrand are as follows:

1. The absence of any action on the anode thus rendering it permanent, and avoiding byproducts formed by its dissolution.

2. As a consequence of the foregoing, a very wide latitude in the current density which may be employed, in contrast with the behavior of the iron anode, which rapidly succumbed to the effects of a high current.

3. The permanence of the cathode, which instead of being

melted down every month in order to recover the values deposited, remains in its place the whole time.

Notes and Comments.

Current Strength.—The question of how to regulate the current so as to obtain the greatest efficiency with the least loss is a difficult though important one. It will be seen that though the anode will permit the use of a very high amperage, yet when the point necessary for the formation of a non-adherent deposit is reached, any additional increase of current will mean an increasing loss of effectiveness in such current, and also a reduction in the amount of cyanide regenerated, and possibly even a destruction of cyanide already free in the solution. We have to consider:

1. The amount of metal held in solution.
2. The amount of solution per hour running through the boxes.
3. The area of electrode surface.

In considering the variation of these quantities we have found the following tendencies:

1. If we suppose the electrode area and amount of solution per hour to be constant, and if we increase the amount of metal in solution we may then increase the current in proportion and get so much more metal precipitated.

2. But if, on the other hand, we keep the area and amount of metal per ton constant, and increase the quantity of solution, a corresponding increase of current gives a disproportionate and continually diminishing effect.

3. If again, we retain the same quantity of solution per hour and the same value of solution, but increase the electrode surface an equivalent of the same current density as before (only spread over a greater area, and therefore proportionately less) will give a greater efficiency in metal precipitated. Thus, even in our modified method of working, Mr. von Gernet's statement on this subject will still to a great extent hold good. At a meeting of the Chemical, Metallurgical and Mining Society of South Africa, on August 18, 1894, in a paper on "Electrical Precipitation of Gold," after calling attention to the fact that, owing to the weakness in metal of ordinary cyanide plant solutions an artificial diffusion of the liquid is necessary, he says, "but it is still more important to give a very large surface to the electrodes. In fact, a better effect is obtained by doubling the number of plates than by increasing the current tenfold."

The tendency would appear to be, then, that the current strength ought to vary as the amount of metal in solution, but that the electrode area should vary as the quantity of solution or speed of flow. The last case, viz., the determination of the electrode area, will also be influenced somewhat by the amount of metal in solution—to this extent, that, as Mr. von Gernet points out, a solution weak in metal will need a much larger area than one rich in metal—but from an electrolytic point of view we might class all solutions from a cyanide plant as being "weak in metal," so that variations in area due to this cause will be very small as compared with those necessitated by variations in the amount of solution passing per hour.

What the ratio is between anode area and amount of solution is difficult to determine. Of course, it is easy to find out in any given case by experiment what ratio will give the best practical results, but we have not yet succeeded in establishing a rule applicable in general. Nor does Mr. von Gernet help us much on this point. In the above-mentioned paper he states that to precipitate 100 tons of solution (containing 5 dwts. of gold per ton) in twenty-four hours 10,000 square feet of cathode surface are necessary, but he does not say how this figure is obtained, nor under what circumstances and to what extent it is variable. Of course, working as we do for a non-adherent deposit, we can make up for deficiencies in electrode area to some extent, by raising the current density, but this, as I have already pointed out, is a wasteful proceeding, and to be avoided, if possible.

The correct relation of quantity of solution to electrode area, *i. e.*, the most economical adjustment of one to the other, is a question I am obliged to leave unanswered for the present for want of sufficient data. I will, however, give some working figures from the Prietas plant to illustrate my contentions in this section of my paper. I will take for this purpose November and December, 1901, because I happen to have the figures for those months by me, and am writing at a distance from Prietas.

1. *Solutions from Sand Treatment.*—The total anode area for dealing with this solution was 6950 square feet, and the average flow per hour 9 tons, or 216 tons per twenty-four hours. Putting this into the same terms as Mr. von Gernet's estimate, we have 3217 square feet to precipitate 100 tons of solution per twenty-four hours. (In the present case anode area is equivalent to cathode area.) The other conditions were as follows: Current density, 0.55 ampere per square foot; voltage between the electrodes about 3 (varying slightly in different compartments). Value of solution, average over the two months in question:

Entering.		Leaving.		Percentage precipitated	
Gold	Silver	Gold	Silver		
dwts.	ozs.	dwts.	ozs.	Gold	Silver
2.03	3.51	0.26	0.29	91%	91.7%

Thus the total value of the tail solutions was equivalent to about 10 grains of gold per ton. As we never used this solution for final washes, we did not think it profitable to spend more power in reducing the value any lower.

2. *Solutions from Slime Treatment.*—The total anode area allotted to this solution was 13,536 square feet, and the average flow per hour 20 tons, or 480 tons in the twenty-four hours. Thus, to precipitate 100 tons of solution per twenty-four hours we were using 2818 square feet of anode. The current density was 0.3 ampere per square feet; the voltage between the electrodes about 2.6. Value of solution, average over two months:

Gold	Silver	Gold	Silver	Gold	Silver
dwts.	ozs.	dwts.	ozs.		
1.10	1.45	0.13	0.15	88%	89.6%

or a total tail value equivalent to about 5 grains of gold per ton. On several occasions during this period it happened that the flow of solution was cut down to about two-thirds of the normal flow, for a day or two at a time, with the following result in assay value of outflow: Gold, 0.05 dwts.; silver, 0.06 ozs. Whether, owing to re-solution of metal, or to mechanical losses of impalpable slime in suspension, this is about the lowest tail value we ever succeeded in getting at Prietas, being approximately equivalent in value to 2 grains of gold per ton.

The foregoing will give a rough idea of the ratio between electrode area and quantity of solution which may be expected to give workable results under conditions similar to those described. I will next give a few figures on tests I have made, illustrating the effect of some varying conditions in the boxes.

First Experiment.

The solution from the slime plant was divided into two equal streams, and treated under two different systems.

System No. 1.—Half the above solution was run through two boxes in tandem, which were in the same circuit and run by a separate dynamo, and were furnished with a current of 0.3 ampere per square foot. (This dynamo was indicating 250 amperes and 25 volts.)

System No. 2.—The other half of the solution was run through a single box, wired so as to give 0.7 ampere per square foot and also having its own dynamo, which indicated 200 amperes and 38 volts.

Thus the amount of solution and its value were the same in

each case, but in No. 2 there was one-half the electrode surface and more than double the current density of No. 1. The average assay over ten days was as follows:

Inflow.

Gold, dwts.	Silver, ozs.
1.30	1.56

Outflow.

System No. 1.		System No. 2	
Gold, dwts.	Silver, ozs.	Gold, dwts.	Silver, ozs.
0.15	0.16	0.23	0.25

Thus, not only did the increase of current density not make up for the deficiency in surface in No. 2, but it also caused a waste of power, using 7600 watts as against 6250 watts for No. 1 system, or nearly 2 hp. more. The test shows, however, that deficiency in area can be largely compensated for by increase in current, though the remedy is not economical.

Second Experiment.

The current density in system No. 2 was raised to 0.8 ampere per square foot. Average assays over three days:

Inflow.

Gold, dwts.	Silver, ozs.
1.46	1.70

Outflow.

System No. 1.		System No. 2.	
Gold, dwts.	Silver, ozs.	Gold, dwts.	Silver, ozs.
0.17	0.20	0.23	0.26

It would thus seem that the current used in the first experiment, system No. 2, was about the limit, beyond which any increase had practically no effect on the value of the outflow.

approximately the extent of such waste. The total gold, silver and copper from each box cleaned up was carefully estimated, including values in slag. This total was then divided by the number of ampere hours required to produce it, and the result compared with the theoretical amount of metal which might have been deposited, determined by taking the theoretical rate of deposition for the three metals, gold, silver and copper, in the proportion in which they were deposited, and making an average of them, and then calling such an average the theoretical rate of deposition of such a gold-silver-copper alloy. For instance, in the case of one box (the first sands box) the average proportion of the metals cleaned up during two months was as follows:

Gold	3.16%
Silver	81.14%
Copper	15.7 %

Then if the theoretical rate of deposition per ampere hour be

For gold (monovalent)	113.17 grains
For silver (monovalent)	62.11 "
For copper (bivalent)	18.62 "

the weight of gold-silver-copper theoretically capable of being deposited by 1 ampere in one hour would be (in this box) 56.83 grains. Thus we need a different theoretical standard for each box, according to the proportion in which the three metals are precipitated. Before giving the results of this test in table I. it will be well for me to explain what the different boxes are which are there mentioned. No. 3 is the first box to receive the solution leaching off the sands plant. On leaving the tail of box 3, this solution passes directly into No. 6, and from the tail of No. 6 into the storage tank. Boxes 1 and 2 are those into which the solution from the slimes plant first runs; and from the tail of 1 and 2 this solution passes into 4 and 5, and so out to the storage tank.

Table I.

Taken over two months, November and December, 1901.

Box Numbers.	Clean-up from All Sources (Ounces Troy)				Total Number of Ampere-Hours.	Grains of Gold-Silver-Copper Actually Deposited per Ampere-Hour.	Grains of Gold-Silver-Copper Theoretically Capable of Being Deposited per Ampere-Hour in this Box.	Theoretical Percentage of Ampereage Wasted.
	Gold. Ounces.	Silver. Ounces.	Copper. Ounces.	Total. Ounces.				
No. 3.....	1,336	34,297	6,633	42,266	2,698,104	7.52	56.83	86 76
No. 6.....	410	10,388	4,678	15,476	2,453,808	3.02	50.19	93.90
Nos. 1 and 2..	775	20,840	15,139	36,754	2,821,778	6.25	45.12	86.10
Nos. 4 and 5...	208	5.368	6,477	12,053	3,029,950	1.90	39.41	95.17
Totals.....	2,729	70,893	32,927	106,549	.....	....	.....	.....

Third Experiment.

No. 1 system remained as in the previous test, but No. 2 system was composed of two boxes, in tandem, wired so as to give a current density of 0.37 ampere per square foot. (Dynamo for No. 2 indicated 240 amperes and 35 volts.) Average assays over ten days:

Inflow.

Gold, dwts.	Silver, ozs.
1.21	1.54

Outflow.

System No. 1.		System No. 2.	
Gold, dwts.	Silver, ozs.	Gold, dwts	Silver, ozs.
0.13	0.14	0.14	0.16

Thus, with equal electrode surfaces, there was absolutely nothing gained by expending an extra 3 hp. on current, tending to show that in system No. 1, other conditions being equal, 0.3 ampere per square foot was the maximum which could be profitably employed. I have figures of other experiments showing in the main, similar results, but to describe them all would unduly draw out my paper.

Waste of Current.—It will be obvious that the current used under the foregoing conditions will be very much in excess of the theoretical amount necessary to deposit the quantity of metal present.

Figures were kept for two months to try and determine

The current was supplied by three dynamos, and the current density was for slimes solution 0.3 ampere per square foot of anode, and for sands solution 0.55 ampere per square foot.

It will be seen that the current used is enormously in excess of that theoretically necessary but in considering this method of precipitation as compared with others, account must be taken of the fact that the item of power is practically the only expense involved; and as we shall see in the following section, a part even of this expense is offset by the value of the free cyanide which is regenerated during precipitation. The average current leaving the dynamo during the two months covered by the test was 25,626 watts, or about 34 hp., and requiring actually about 50 i. h. p.

Regeneration of Cyanide.

Before giving any figures under this head, I will quote a passage from Mr. Walter McMillan, which may help to explain what occurs during precipitation. ("A Treatise on Electro-Metallurgy," by Walter McMillan; second edition. Charles Griffen & Co., Ltd.) Page 198:

"In passing the electric current through a solution of silver

potassium cyanide ($KAg(CN)_2$), the double cyanide is broken up into the cation K, and the anion, Ag $(CN)_2$. The potassium is deposited at the cathode, but by chemical exchange displaces from the surrounding solution of the double cyanide an equivalent of silver (which deposits on the cathode) and forms potassium cyanide in the liquid (thus: $KAg(CN)_2 + K = Ag + 2KCN$). Thus there is a centration of potassium cyanide around the objects which are being plated. The silver travels in the anion $Ag(CN)_2$ to the anode, where the ion decomposes into AgCN + CN, and the cyanogen (CN), set free, attacks the silver anode to form another molecule of AgCN. Hence, at the anode there is formed a double quantity of the insoluble compound AgCN. It is therefore necessary that a good excess of free potassium cyanide be present, to combine with the silver cyanide (which would otherwise form an incrustation on the anode) and thus to form the soluble double cyanide, whereby the silver is carried into solution and the anode is left bright throughout." Again, on page 360, the same explanation is given in the case of potassium aurocyanide.

Now, the foregoing reactions are given with reference to a soluble anode, but if we suppose the anode to be an insoluble one, the result would appear to be as follows: At the cathode the K cations react with $KAgCy_2$, according to the equation

$$K + KAgCy_2 = 2KCy + Ag$$

at the anode the anion $AgCy_2$ splits up according to the equation

$$AgCy_2 = AgCy + Cy.$$

Thus, at the end of the reaction we have on the cathode side Ag (which remains on the cathode), and 2KCy in the solution; while on the anode side we have AgCy and Cy. If, then, we take one molecule of KCy from the cathode side and combine it with AgCy on the anode side, we have $KAgCy_2$; so that when the anode is not soluble we have one molecule of KCy left free in the solution (representing potassium cyanide regenerated) and also Cy. So that we might summarise the total reaction thus:

$$KAgCy_2 = Ag + KCy + Cy$$

showing for every molecule of potassium-silver cyanide a regeneration of one molecule of potassium cyanide.

Table II.—Sands Solution.
Average Strength in KCN.

Month.	Tail of Box. Per Cent.	Head of Box. Per Cent.	Increase. Per Cent.
September, 1902	.10745	.09618	.01127
October, 1902	.08329	.06835	.01494
November, 1902	.09305	.06732	.02573
December, 1902	.09400	.08357	.01042
January, 1903	.09123	.08061	.01062
Averages	.09380	.07920	.01460

Slimes Solution.
Average Strength in KCN.

Month.	Tail of Box. Per Cent.	Head of Box. Per Cent.	Increase. Per Cent.
September, 1902	.06254	.04654	.01600
October, 1902	.05235	.04164	.01071
November, 1902	.05458	.04200	.01258
December, 1902	.04343	.03614	.00729
January, 1903	.05046	.03800	.01246
Averages	.05267	.04086	.01181

In the above reaction it is assumed that the current density is in proper proportion to the metal present in solution. Should, however, the current be in excess, or, in other words, should K be deposited on the cathode so fast that it cannot find enough of the potassium-silver cyanide in the neighborhood of the cathode to react upon, the excess will decompose water and deposit hydrogen, and the amount of KCy finally regenerated will be diminshed. Now, as to actual results obtained. Regeneration of cyanide is a phenomenon which is very noticeable when working under the conditions described above, though I do not remember that it attracted attention during the discussion on the electrolytic process in South Africa, where indeed it would not be likely to be in evidence owing to the difference in conditions of working. On a few occasions when working on the Rand, I noticed a slight rise in cyanide strength after the solution had passed through the box, but in each case it was so small that it might have been accounted for by a difference in the finishing point of the titration, and I did not follow it up by making any systematic tests. At Prietas, however, where my attention was first called to it by Mr. Durant, I have made repeated experiments to verify this, the test in one case running over five consecutive months; the results are given in table II. (samples taken by hand every two hours, and test made on each day's composite sample).

From table II. it will be seen that the average increase in strength caused by passing through the boxes (taken over five months) was:

For sand solution ..... 0.0146% KCy
For slime solution ..... 0.0118% KCy

or, in other words, for every 100 pounds of solution which passed through the sand solution boxes 0.0146 pound of KCy was regenerated, and for every 100 pounds passing the slime boxes 0.0118 pound of KCy was regenerated. Now, the relation of the amount of ore treated to solution going through the boxes was: For sands, 1.2 tons of solution per ton of sand; and for slimes, 4 tons of solution per ton of slime, so that for every ton of sand treated we recovered 0.35 pound of cyanide, and for every ton of slimes 0.94 pound. Then, if the slimes be taken to constitute 40 per cent of the tailings treated, we have a total saving in cyanide of 0.58 pound per ton of ore treated during the period covered by the test. (I may here mention incidentally that the total average cyanide consumption on the plant was from 2.5 to 3 pounds per ton of ore.)

The difference in cyanide recovery between sands and slimes is very noticeable, and the following would seem to be the way to account for it: From the precipitation table I. it will be seen that the slime boxes yielded nearly double the amount of copper which was recovered from the sand boxes; if, then, this copper be considered to be in solution in the cupric form, one ounce of it would furnish about three time as much KCy as a similar weight of silver, and about six times as much as a similar weight of gold. Table I. does not cover the same period as table II. on cyanide regeneration, but is sufficiently representative to be used as an illustration. If the weights of gold, silver, and copper precipitated in the sands and slimes boxes, respectively, be considered in regard to the possible KCy they could furnish in the act of being precipitated, the slimes box will have a very marked advantage, especially when it is remembered that this box only deals with 40 per cent of the total tonnage of ore treated.

In order to see how the amount of cyanide actually recovered per ton of ore compared with the theoretical amount capable of being regenerated in accordance with the foregoing reaction, the total gold, silver and copper precipitated during the five months covered by this test was divided by the total number of tons treated. This gave an average of

Gold, ozs.	Silver, ozs.	Copper, ozs.
0.12	2.57	5.88

precipitated per ton of ore treated. Then, taking as a basis the equations

$$KAuCy_2 = Au + KCy + Cy$$
$$KAgCy_2 = Ag + KCy + Cy$$
$$K_2CuCy_4 = Cu + 2KCy + 2Cy$$

we have a cyanide regeneration of 0.93 pound per ton of ore treated, as against 0.58 pound actually recovered per ton of ore.

Now the theoretical figure taken, if correct, could only be so when the current is so adjusted as to cause no decomposition of water; but, as a matter of fact, there is in the boxes a very lively decomposition of water, and therefore a loss of available potassium cyanide, KOH being formed at the cathode and H being liberated; and such loss would seem to be far greater than the difference shown between the actual and theoretical amount of KCy regenerated; consequently, it would seem legitimate to suppose that the Cy shown to be liberated at the anode combines to some extent with the KOH in the solution to form free KCy, thus:

$$2Cy + 2KOH = KCy + KCyO + H_2O$$

In this case, there would be going on simultaneously a very active decomposition and recomposition of free KCy, and our free cyanide actually shown by test to be recovered would represent the difference between these two tendencies.

Mr. M. F. Perry, the general manager at the Minas Prietas Works, informs me that lately, since they have been treating the ore direct from the mine, without any previous amalgamation or concentration, the regeneration of cyanide has decreased very considerably. One cause which would make this more apparent, would be the absence of copper in the solution. The only other difference in conditions would seem to be the increase in the amount of silver sulphide in the ore. I have heard several cyanide chemists give it as their opinion that, in the case of treating Ag_2S with potassium cyanide, the silver sulphide is decomposed and gives up its sulphur to the potassium; but Dr. Rose ("Metallurgy of Gold") states reasons for believing that silver sulphide is in some cases directly soluble, without decomposition, in strong (and even in weak) solutions of cyanide. It is difficult to suggest reasons for the decrease in regeneration of KCy in the present instance without knowing exactly in what form the silver comes into the boxes.

Lime Precipitation.

One drawback we have encountered in working out this method is the precipitation of the lime held in the solution. It is chiefly noticeable in the slime solution boxes, and more especially the second set, into which the solution flows after leaving the first set of boxes. It has sometime formed as much as 30 to 40 per cent of the precipitate cleaned up from these boxes, and, of course, has added very much to the difficulties of smelting. An incrustation, chiefly composed of calcium carbonate, also forms on anodes, which have not been thoroughly peroxidised. The anodes we made during the first two years or so gradually wasted away, and in the process accumulated the heavy white crust above mentioned; but, as I said in the first section of this paper, anodes peroxidised under the conditions there stated, have, up to the present, shown no change of surface, whatever. An analysis of this crust, made for me by Messrs. Lehman, of Baltimore, Md., showed the following constituents:

Moisture	0.275	per cent
Loss upon ignition	6.060	"
Calcium oxide	41.580	"
Carbonic acid	31.120	
Lead metallic	13.530	"
Iron oxide	0.540	"
Copper metallic	0.750	"
Sulphuric acid	4.400	"
Chlorine	0.670	"
Vanadium	0.095	"
Silver	0.126	"
Gold	0.003	"
	99.149	per cent

Why the lime is thrown out of solution, I am unable to say; it might be possible to represent the reaction by the following:

$$2CN + 2KOH = KCN + KCNO + H_2O$$
$$KCNO + 2H_2O = NH_3 + KHCO_3$$
$$KHCO_3 + Ca(OH)_2 = CaCO_3 + KOH + H_2O$$

A smell of ammonia is often distinctly perceptible in the atmosphere around the boxes, especially those in which most lime is precipitated. But the above explanation would not appear to be sufficient to account for the facts, if it indicates nothing more than a substitution of potassium hydrate for calcium hydrate in the solution, for this reason: when trying various methods to reduce the amount of lime in the precipitate, I cut down the free lime in the working solutions to the lowest point compatible with proper settlement of the slimes. Under these conditions, solution which showed 0.005 per cent of lime (by alkalinity test) when going into the boxes, did not show a trace of free alkali after passing through. This last fact would, perhaps, point to a decomposition of KOH by the Cy liberated at the anode, as suggested in the preceding section. If this should be so, the addition of caustic potash at the head of the box might result in an increase of free cyanide regenerated. I hear that Mr. Clive Newcomb, who now has charge of the precipitation of Prietas, is experimenting with a drip of caustic potash with this end in view, independently of any suggestions contained in this paper, but I have not received any figures on this test.

As regards the lime, it is possible that $CaCO_3$ is not formed in the first instance, but that the calcium combines directly with the Cy at the anode to form $CaCy_2$, which then undergoes further changes.

The only way we have so far found to abate the nuisance is to reduce the current density employed; the tendency increases with increase of current, and *vice versa.* This would be another reason, in addition to those given in earlier sections of the paper, for having sufficient electrode area to be able to use the lowest current density compatible with a proper sliming of the metal precipitated.

Conclusion.

As regards the usefulness of this method of electrolytic precipitation it is possible that it would not be advantageously applied in the case of a proposition where the metal to be deposited is almost exclusively gold—this could only be found out by trial—but where the values are largely composed of silver (implying a considerable weight of metal to be thrown out of solution) it would seem likely to be very serviceable, and in cases where large quantities of copper are dissolved in company with the gold and silver, the method would probably be found exceedingly valuable.

As regards the data given in this paper, I have taken pains to make them as correct as possible, and I think they can be taken as accurately representing the facts. In carrying out experiments and obtaining the above-mentioned data, I have to acknowledge the valuable assistance, first, of Mr. W. Mosher and later, of Mr. Charles Morgan, and Mr. Harry Freiburger.

Copala, Smaloa, Mexico.

METRIC SYSTEM IN MEXICO AND IN CUBA.

In a consular report from Durango, Mexico, it is stated that the metric system has been very generally adopted by the people in Mexico, and is in use in ordinary practice, as well as being the official measures of weight and capacity. In the building trades, for example, the meter is the ordinary standard for linear, square, and cubic measure, and the ordinary workmen in the carpenter's, stone cutter's, and brick or adobe layer's trades use the meter rule for their work as a general thing. In smaller carpenter shops they still express themselves for purposes of comparison in Spanish feet and inches (pulgadas) at times, but the meter rule is their

guide and smaller measures are ordinarily determined in centimeters. The architects of the country have in the main adopted the metric system; the exceptions to this rule are American or English architects who are temporarily engaged in putting up buildings here, and who quite generally cling to the old measures familiar to them. The Mexican National Iron and Steel Company (which operates the "Iron Mountain" here) turns out iron for structural purposes both in feet and meters, according to the way the plans are drawn. Their manager states that architects from the United States generally express their measurements in feet.

In a report of Consul M. J. Baehr, of Cienfuegoes, Cuba, it is stated that the metric system of weights and measures is established by law and is adopted in all transactions at the custom house, city hall, and in the registry and records of property; in fact, it is compulsory and adhered to in all official acts. In ordinary life, however, in groceries, in the sale of the country's products, such as cereals, the pound is still adhered to. Civil engineers and land surveyors in Cuba employ the metric system throughout their measurements. Mechanics in general make use of English inches as their unit measure.

THE RELATION BETWEEN ARSENIC AND ELECTROMOTIVE FORCE IN COPPER-ELECTROLYSIS*.

By L. Webster Wickes.

The bad effects of arsenic in commercial copper are well known to metallurgists. The refining of copper by electrolysis eliminates practically all of the arsenic, provided certain requirements are fulfilled. The first, and most important, of these requirements is that the voltage of the depositing current shall not be too high. It has been known for some time that the percentage of arsenic in the deposited copper increases with the voltage.

To investigate the relation between the e. m. f. and the freedom of the precipitated copper from arsenic, the experiments were made, of which a brief summary is here given. I made three copper-arsenic alloys, containing respectively 3.56, 2.24 and 0.96 per cent of arsenic. From these alloys I cast several anodes. For cathodes I used sheets of thin copper, coated on one side with "mounting wax," and on the other with a thin film of graphite. Vaseline was used to make the graphite adhere. During electrolysis the copper was prevented from depositing on one side of the cathode by the wax, while the copper deposited on the other side was readily stripped off to be weighed, analyzed, etc. The electrolyte used was that suggested in Peters' Modern Copper Smelting, viz.: $H_2O \div CuSO_4 \div H_2SO_4 = 75 \div 19 \div 6$. The electrodes were 6 by 8 inches, resting in 5-liter vulcanite vats. Electrolytes were circulated by air.

I set up three sets of three vats, each connected in series, and each containing an anode from each of the three alloys. The current used in each set of three cells was so regulated that the cell-drop of the first set was 0.8 volts; of the second, 0.6 volts; and of the third set, 0.4 volts.

The amperes of the first set were 5.5, and of the second and third were 4. The difference in voltage of the second and third was obtained by decreasing the distance between electrodes.

The question was raised, whether the higher voltage, due to the greater distance between the electrodes, would have the same effect as increasing the voltage by increasing the current, and keeping the cell-resisting constant? Undoubtedly increasing the e. m. f. by increasing the current changes the drop from anode to solution, and from solution to cathode, as well as through the solution. But, since the energy set free by the solution of a metal is equivalent to that required to precipitate from the solution, they will always balance each other.

I found that, with different voltages, but with the same percentage of arsenic in the anode, the percentage of arsenic in the cathode per weight of copper is practically the same, whether the difference of voltage is due to difference in the distance between the plates, or to difference in amperage.

I set up four more vats, using the 2.24-per-cent-arsenic alloy for anode in each. To the electrolyte of each was added 0.101 per cent As in the form As_2O_3. The first of these cells had 2.5 inches, and the second 1.5 inches between the plates; and passing 4.5 amperes through the first, and 9.5 amperes through the second, gave them an equal cell-drop of 0.95 volt. The electrolyte was the same in both. In cell No. 3 a less acid electrolyte was used than in cell No. 4 (other conditions being the same as in Nos. 1 and 2), but brought up its conductivity to that of No. 4 by the addition of potassium sulphate. The cell-drop of each was 0.95 volt when No. 3 had 2.5 inches between plates and 4.5 amperes, and No. 4 had 1.5 inches between plates and 9.5 amperes. No. 3 was kept quite warm.

Two important facts were noted:

1. Whenever the main current was shut off, a certain voltage was always shown in the cell.

2. This voltage was always in the same direction as the original current.

Of the four cells last described, the percentage of arsenic per weight of copper was less in No. 3 than in No. 1, and less in No. 1 than in No. 2 and No. 4.

Since a certain voltage was shown in the cells when the main current was interrupted, and that said voltage being in the same direction as the main current voltage, it is evident that, as the electrodes are identical with the exception of the arsenic, the arsenic passed into solution as cations, or out of solution as anions. In either case the result is the same. It is impossible for anions to exist on the cathode. Therefore, to produce this voltage, the arsenic must pass into solution as metallic arsenic, and from the solution it becomes sulphate. To be deposited on the cathode, it must continue to exist as cation. In this water solution the arsenic hydrolyzes and becomes arsenate. When hydrolyzed it cannot be deposited. Hydrolyzation is a function of the time the ion is in contact with the solution. In other words, the more time the arsenic has to hydrolyze, the smaller will be the percent of arsenic in the deposited copper. As the amperes increase, the time for hydrolyzation decreases. The hydrolyzation in cell No. 3 was greater than that in No. 1 (less acid and warmer), while both gave greater length of time than Nos. 2 and 4.

From the above, I think it follows that the percentage of arsenic in the cathode is only *indirectly* a function of the voltage in so far as that is a function of the amperage, and is *directly* a function of the degree of hydrolyzation of the sulphate. The investigation of the exact limit to which the hydrolyzation of the arsenic sulphate could be carried without the production of the copper oxide, I was forced to abandon for the time being.

The arsenic was added to the second group, consisting of the four cells, to bring the electrolyte up to the condition it would be in after a considerable run. The arsenic in the successive cathodes was not increased thereby, as is the case with electrolytes high in arsenic, due to a long run. This fact would seem to indicate that the arsenic in the solution, after a run, was not in the form of As_2O_3. Mr. W. McA. Johnson, in one of his papers,[1] says that "The oxide of arsenic present in an anode is an insulator, and thus passes into the slimes." The arsenic seems, therefore, to have another "phase." So far, this has not been investigated. Another question which I have so far been unable to answer is, what effect has the condition in which the arsenic exists in the

*Paper presented at the Atlantic City meeting of the American Institute of Mining Engineers. It is an abstract of a thesis presented, in partial fulfillment of requirements for the degree of metallurgical engineer, to the Faculty of Applied Science, Columbia University, New York city. The full text of this thesis, with tables, curves, etc., is in the library of the Department of Metallurgy at the university, and may be consulted by those desiring more detailed information.

[1] Transactions of the American Electrochemical Society, vol. [illegible] p. 177.

anode on its distribution throughout the cathode, electrolyte and slimes, or its combination with silver, etc.? A careful research in this field, as well as along the line of the form or phase of the arsenic during the different stages, will be necessary before definite conclusions can be reached.

The opinions here brought forward are the result of the analysis of nearly 200 depositions of cathode copper, and electrolytes. The experiments were carried on in the Department of Metallurgy of Columbia University, to which I am greatly indebted for the opportunities offered, as well as to Professors Morgan and Miller, of the Department of Chemistry, for much valuable help and many suggestions.

ALUMINIUM: A NEW PROCESS OF M. GUSTAVE GIN.

By P. McN. Bennie.

For almost a century inventors have struggled with the problem of extracting that widely distributed element aluminium from the various compounds in which it occurs. Many processes have been conceived, some impossible, others impracticable, and still others too costly to ever find commercial application. The prize of a successful process has been sought most zealously, but finally the field has narrowed down to two processes which have survived the supreme test of successful commercial application, those of C. M. Hall and Paul Héroult.

One would think that almost every experiment in the gamut of possibility had been thought of and tried, but still the search goes on. A number of processes have been patented within the last two years, by Hohman, Rubel and Bernstein, Reuterdahl, Blackmore, Schwahn, Jensen, and others. Gin[1] proposed to produce aluminium by decomposition of an electrolyte consisting of a mixture of molten aluminium fluoride and sodium sulphide. Taddei[2] proposed to electrolyse fused sodium chloride, bring the chlorine into contact with a mixture of tar and dehydrated alumina, form aluminium chloride and carbonic oxide, and then pass the aluminium chloride in the form of vapor into another vessel, where it would come into contact with sodium vapors generated by the primary step in the process; the sodium combining with the chlorine of the aluminium chloride, forms sodium chloride and free aluminium.

M. Gin has recently patented still another process,[3] which seems to attack the elusive problem in a different way. The interest which attaches to aluminium processes generally seem to justify some notice of the process, which has been reviewed at length by M. Becker, in *l'Industrie Electro-Chimique*, for December, 1903.

* * * * *

The process of Sainte-Claire-Deville for the manufacture of aluminium, which had been in operation in France at Nanterre and Salindres, was finally abandoned on account of the high price of sodium, and aluminium chloride.

Grabau[4] appears to have been one of the first to conceive an advance towards a commercial process, by proposing the addition of sodium chloride to the electrolytic bath, as furnishing simultaneously the alkali reducing metal (sodium), and the chlorine required for the preparation of aluminium chloride.

Others,[5] among whom were Basset & Seymour, have claimed to substitute zinc for sodium, as reducing agent, by observing that, while zinc does not decompose pure aluminium chloride, it reduces the double chloride of aluminium and sodium, at a red heat. Basset obtained in this way an alloy of zinc and aluminium. This reaction was never applied industrially, and does not seem to have been commercially practicable.

M. Gin claims, however, that it is easy to effect the reduction of aluminium chloride, by the substitution of zinc-sodium alloy for the zinc, according to the following reaction:

$$2Al_2Cl_6 + 3ZnNa_2 = Al_4 + 3(ZnCl_2.NaCl),$$

by using simultaneously the zinc and sodium for the reduction.

Thermochemistry shows that at temperatures higher than the point of volatilization of the double chloride of aluminium and sodium—but still inferior to that of the double chloride of zinc and sodium—the system $2Al_2Cl_6 + 3ZnNa_2$ has a potential energy greater than that of the system $Al_4 + 3(ZnCl_2 + 2NaCl)$. It is therefore the latter which is formed by virtue of the principle of "maximum work."

It is admitted that the economy resulting from the substitution of the zinc-sodium alloy for pure sodium, is not sufficient, and that it is desirable to render the preparation of the aluminium chloride more economical by starting directly—not with pure alumina, but with bauxite, the least costly of the minerals of the aluminium series.

Upon these principles M. Gin has based a process for the manufacture of aluminium, consisting of the reduction by zinc-sodium alloy, of aluminium chloride prepared from bauxite by means of the chlorine disengaged by the same electrolytic operation which furnishes the zinc-sodium alloy.

The reduction which finally yields the metallic aluminium also reconstitutes the double zinc-sodium chloride in such fashion that the various operations form a closed cycle, with regeneration of the intermediate compounds, of which the successive phases may be illustrated by the following formulæ:

I.—*Chlorine and Zinc-Sodium.*

(1) $ZnCl_2.2NaCl + \text{electric energy} = Zn + 2NaCl + Cl_2$

$2NaCl.KCl + Zn + \text{electric energy} = ZnNa_2 + KCl + Cl_2$

II.—*Aluminium Chloride.*

(2) $Al_2O_3 + 3C + Cl_6 = Al_2Cl_6 + 3CO$

III.—*Reduction by Zinc-Sodium.*

(3) $2Al_2Cl_6 + 3ZnNa_2 = Al_4 + 3(ZnCl_2.2NaCl).$

In order to show how this is carried out in practice, M. Gin describes in detail the various phases of manufacture.

The chlorine and zinc-sodium alloy are prepared by electrolysis on one hand of the double chloride $ZnCl_2.2NaCl$, and on the other the chloride $2NaCl.KCl$. These two operations disengage chlorine, the first supplying the zinc destined for the cathodic bath of the second, in which is prepared the alloy $ZnNa_2$ (about 40 per cent of sodium).

The electrolysis is carried out with a cathode consisting of an iron crucible, lined with agglomerated carbon; the anode consists of a bundle of cylindrical carbons. These carbons are fitted at the upper end into a cap, or holder, having the form of an inverted box, of which the lateral walls are grooved into a channel surrounding the crucible, and filled with water so as to form a hermetically sealed hydraulic joint. It is said that the best results are obtained by conforming to the following values:

	Zinc.	Sodium.
Density of current at cathode	0.25	0.50
Density of current (cross-section of anodes)	1.00	2.00
Temperature of system	450°C.	580°C.
Voltage of system	3.7 to 4	6.6 to 7

M. Gin admits that the electrolytic apparatus for the manufacture of sodium and its alloys are very numerous and well known, through the work of such men as Rogers, Vautin, Borchers, and others. He does not claim either the principle of electrolytic preparation of zinc-sodium, or the apparatus described, as any other arrangement may be substituted, providing it conforms to the conditions given.

---

[1] British Patent 964, 1903.
[2] U. S. Patent 715,625, December 9, 1902.
[3] French patent 334,132, July 25, 1903.
[4] Electric Smelting and Refining, second edition, Borchers.
[5] For instance, Kagenbusch, English patent 4,811, 1872.

While theoretically the zinc chloride should be reformed during the course of the operations, it is necessary to add regularly a certain quantity to compensate for losses due to divers causes, notably to the fixation of chlorine by the iron and silica of the bauxite.

The zinc chloride may be obtained in various ways, but it is found that the most economical method consists in submitting zinc blende, as pure as possible, and mixed with sodium chloride, to the well-known process of roasting.

The zinc chloride thus formed, which is volatile at 710° C. is collected by sublimation. It is freed from iron by passing it over zinc oxide:

$$Fe_2Cl_6 + 3ZnO = 3ZnCl_2 + Fe_2O_3$$
$$(+ 40.5 \text{ calories.})$$

The other contained metals and metalloids are eliminated by remelting the sublimed chloride in a bath of metallic zinc. It is evident that it is desirable to work only with rich blendes, to reduce to a minimum the intervention of the metallic zinc treatment.

The aluminium chloride is prepared by the classic method of Sainte-Claire-Deville, but with the substitution of bauxite for pure alumina. The bauxite, mixed with 25 per cent of its weight of anthracite coal, is pulverized, then agglomerated with addition of 10 per cent of tar, into oval balls or briquettes. These briquettes are calcined, and then treated with chlorine, in a suitable chlorination apparatus, such as a vertical retort.

The gaseous products of the reaction pass into a condenser, where the aluminium chloride, mixed with ferric chloride, is separated. The permanent gases, and the silicon chloride, pass into a chamber suitably removed from the first chamber, and into which is injected a thin stream of water vapor, which decomposes the silicon chloride into silica precipitated upon the walls of the chamber, and hydrochloric acid, which is gathered with the free chlorine into an absorber containing roasted blende, moistened with water. Zinc chloride is here formed separated by lixiviation, concentrated by means of the waste heat from the chlorination apparatus, and finally added to the blende intended for the chlorination roasting. In this way it is said there is recovered a certain proportion of zinc chloride, which re-enters into the operations.

When a sufficient quantity of impure aluminium chloride has been sublimed, communication is interrupted with the sublimation chamber, as well as with the chlorination retort of which latter the gaseous products are directed into a relay condenser. The sublimation chamber being thus isolated, the liquid zinc is introduced, the chamber hermetically closed and heated gently so as to liquefy the aluminium chloride under its proper vapor pressure. The zinc reduces any ferric chloride present, and sets free the iron. The sublimation chamber is then connected to the reduction apparatus.

In this operation only aluminium chloride is disengaged, the zinc chloride remaining in the chamber, which is now heated to a temperature under 500° C. The aluminium chloride vapors coming into contact with the zinc-sodium alloy are reduced, and there is formed, as has been described, the double chloride of aluminium and sodium, and metallic aluminium, containing, however, several per cent of zinc.

This zinciferous aluminium is now poured into the channel or canal which forms the crucible of M. Gin's electric incandescent furnace, which consists of a canal of relatively great length and small cross-section, doubled several times upon itself, upon a hearth of refractory material. (See Electrochemical Industry, January, 1904). The extremities of the canal are connected with blocks of aluminium of large section which serve as connections to the electric current.

A canal of 16 cm. metallic section, containing about 100 kilogs. of aluminium, is said to be purified in several minutes by a current of 10,000 amperes, at 25 volts. The volatilized zinc is collected in metallic receptacles fixed in the walls of the furnace, while the aluminium is cast into ingots. The chloride of zinc and sodium is recovered and returned to the electrolytic apparatus for chlorine and zinc-sodium.

M. Gin claims "the process of manufacturing aluminium, consisting in the reduction of aluminium chloride by zinc-sodium alloy $ZnNa_2$ (about 40 per cent sodium); said process being characterized by the direct attack upon bauxite by chlorine, which chlorine is obtained by electrolysis of the double chloride of sodium and zinc, and of zinc, which furnish simultaneously the reducing alloy; the electrolyte $ZnCl_2.2NaCl$ being reconstituted by the same reduction, in such fashion that the various operations form a closed cycle with regeneration of intermediary products."

* * * * *

It is, of course, obvious that this process involves considerable manipulation, and much carefully balanced chemical treatment. It will be interesting to learn more about such a process if it should be tried upon a commercial scale.

PREPARATION AND COMPRESSION OF PURE GASES FOR EXPERIMENTAL WORK.*

By R. S. Hutton and J. E. Petavel.

Having been engaged for some time past on experimental research dealing with the effect of high gaseous pressure upon electric furnace reactions, the necessity arose of preparing, compressing, and storing several gases which were either not available commercially, or which could not thus be obtained in the desired state of purity. Although a very great deal of information had been published relating to the production of the various gases in sufficient quantities for ordinary laboratory experiments, such methods cannot be easily applied when the required scale of working is considerably larger. On the other hand, the commercial manufacture in some cases has been most carefully worked out, but the plant required is too large and costly to be practical for temporary use.

The object of the present paper is to describe how, with little more than such apparatus as should be available in any chemical laboratory, the preparation of a number of gases can be carried out at a trifling cost, and with due consideration as to their purity. It will be noticed that the equipment is so devised as to be available for use in the different cases with but little modification. Those who look for any novelty in the principles of the methods adopted will, we fear, be disappointed; we venture, however, to think that to the increasing number of workers, who, either for commercial or scientific purposes require, like ourselves, pure gases in considerable quantities, the information which we offer will be of some value.

The apparatus has been devised for gas generation and purification at a rate of about 1 liter per second (130 cubic feet per hour). Hydrogen, nitrogen, carbon monoxide, and ethylene are dealt with in detail. Apart from the information which we have been able to obtain by direct experiment, references are given to several of the more important published accounts dealing with the manufacture on the full commercial scale. For some chemical purposes, the gases would be passed straight from the generator for use in the chemical process for which they were required; on the other hand, it is frequently necessary for convenience to store the gas for subsequent use; in fact, where the experiments are at all general in character, it is advisable to have a stock of different gases constantly available. This involves the erection of compressing and storing plant, even where high pressure *per se* does not play a part in the work. Our account, therefore, includes a description of a small plant which we have found satisfactory for these purposes.

Hydrogen, Its Commercial Manufacture and Applications.

Hydrogen is at present principally employed for inflating military balloons, autogenous welding, and lead-burning

*A paper read before the Manchester Section of the Society of Chemical Industry.

(*Zeitschr. f. Elektrochemie*, 1895, vol. 2, p. 204), and is manufactured in considerable quantities for these purposes. The older and purely chemical methods of generation based on the action of acids or steam on metals are being to a large extent displaced, where a continuous supply is required, by electrolytic processes, the working cost of the latter being considerably lower. Suitable electrolytic cells can now be installed at a reasonable expense.

The plant for the chemical manufacture by the action of acids on metals is of two principal types. The first is a development of the ordinary laboratory "Kipp," and will be described later. The second type is designed to give for a limited time a very large quantity of gas, and in principle consists in employing a tall cylindrical receiver filled with metal turnings or granulated metal, the outflow of gas being regulated by the amount of acid which is allowed to flow into the top of the cylinder, the spent acid being run off at the bottom. This latter method is of the two, by far the more important for large scale working, such as for inflating balloons. In this case some 10,000 cubic feet of gas may be required to fill a single balloon, an operation which has to be effected within a short space of time. The process has also been employed for many years at the Royal Institution for the manufacture of hydrogen in connection with the liquefaction experiments, and at a more recent date by Morris W. Travers, at University College, London (*Phil. Mag.*, 1901 [6], I., 411).

A plant on these lines has been recently constructed by Messrs. Lennox, Benton and Reynolds, Ltd., capable of delivering some 800 cubic feet of hydrogen per hour. The receiver is a copper cylinder about 6 feet high and 1 foot diameter, and contains a charge of 4 cwts. of granulated zinc. As will be seen by the diagram, Fig. 1, the actual generator is mounted in the center between two washing towers, each 8 feet high. The three cylindrical towers, which are open at the bottom, are supported in a cast-iron tank, which forms a water seal and collects the spent acid. The towers are surmounted by two superimposed tanks, the lower one containing a lead coil immersed in water to act as cooling chamber, the upper one, lead-lined, acting as acid reservoir. A spray of water keeps the flints in the two washing towers moist. The rate of flow of the acid is observed through a sight feed.

A. Acid reservoir.

B. Cooling tank.

D. Generator proper.

C and E. Washing towers.

b. Valve regulating admission of acid.

g. Sight feed for ditto.

K. Outlet for gas.

c and *d*. Valves regulating water admission to washing towers.

e and *f*. Sight feed for ditto.

H. Cast-iron tank acting as seal to the cylinders, and into which spent acid flows.

K. Outlet for gas.

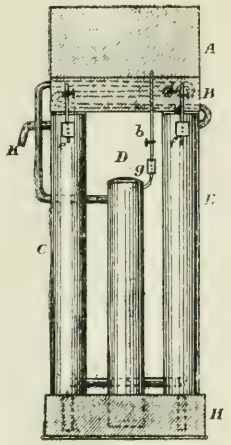


FIG. 1. HYDROGEN GENERATOR PLANT.

(Scale, ½ inch to foot.)

An apparatus of a similar type, the design of Ch. Renard, has been adopted by the French army for field use. The employment of zinc has, however, the serious disadvantage that the gas often contains sufficient arsenic to be dangerous if dealt with in any quantity.* Moreover, the gas generated by the action of acids on ordinary spelter or metallic iron is liable to be considerably more dense than pure hydrogen. (W. Dürer, *Zeitchr. f. Elektrochemie*, 1901, vol. 8, p. 2.) Of other chemical processes, the heating of zinc-dust and soda-lime briquettes is employed in the German army in a portable equipment for balloon inflation, while the reaction between heated iron and steam has recently been applied by the Industrial Engineering Co., who regenerate the iron with producer gas, and have thus brought this method into a convenient and practical form.

The electrolytic manufacture of hydrogen is coming much to the front; in this case, whereas the first cost is relatively high, the working expenses, whenever the plant can be run continuously, are generally lower than for the chemical method. Numerous types of plant have been designed, the principal requirements being a low working voltage and the effectual separation of the hydrogen and oxygen; the latter, particularly where the gases have to be compressed, being of the utmost importance from the point of view of safety. The electrolytic methods will be found described in monographs by Victor Engelhardt and P. Schoop [V. Engelhardt, *Die Elektrolyse des Wassers* (Halle: W. Knapp, 1902); P. Schoop, *Die Industrielle Elektrolyse des Wassers* (Stuttgart: F. Enke, 1901)]; suffice it to say that in principle they can be grouped under three types:

(1) The Schmidt and Ch. Renard systems employ iron electrodes in alkaline solution, the electrodes being separated by diaphragms of asbestos.

(2) The Schoop system, in which each cylindrical electrode is surrounded by tubular diaphragms, has the advantage of absolute safety from any danger of admixture of the gases, but involves some loss of power through additional resistance. In this case lead electrodes are employed in an acid electrolyte.

(3) The Garuti, Siemens Bros., and Schuckert plants employ metallic diaphragms and generally work with alkaline electrolytes.

At the present time almost all the European military authorities have adopted one or another of these electrolytic plants for balloon purposes, but in Germany the government makes use largely of the waste hydrogen evolved in the electrolytic alkali industry, an example which will, no doubt, be widely followed in the future, when it is considered that, even at a moderate estimate, some 240,000 cubic feet of hydrogen are going to waste daily in this way (*cf. Zeit. f. Elektrochem.*, 1895, vol. 2, p. 290). At least three large installations (*Buffa, Bull. de l'Assoc. des Ing. Electr.* (Liège), 1900, vol. 11, p. 305), those at Brussels, Lucerne and Rome, exist on the continent for putting on the market compressed hydrogen obtained by the Garuti process, a notable economy resulting from the fact that the oxygen, which is also compressed, finds a still more ready sale.

A complete consideration of the question of cost would carry us too far, but full details will be found in the monographs referred to. Suffice it to say that, with spelter at £21, (about $102) a ton, a cost of at least some 35s. (about $8.40) is incurred in zinc alone per 1,000 cubic feet of hydrogen obtained, whereas by several of the electrolytic processes the same amount of hydrogen can be obtained for 157 kilowatt hours, which, even at 1d (2 cents) per unit, a high estimate for power generation when used continuously, only amounts to 13s. 1d. (about $3.14). It should be borne in mind that the oxygen produced simultaneously is also of considerable commercial value.

Thus, where an uninterrupted supply of gas is required

*Numerous attempts have been made to remove the arsenic from the gas, amongst which passage through a heated tube or a solution of a permanganate should be mentioned. Recently Ch. Renard has carried out some experiments on the use of liquid air for condensing the arseniuretted hydrogen in connection with the aeronautical department of the French army. It is found that cooling to 110 degs. C. is essential for complete elimination of the arsenic. (C. R., 1903, v. 136, p. 1317.)

throughout the entire year the electrolytic methods offer considerable advantages. Owing, however, to the much smaller capital outlay, the older chemical process is preferable when the hydrogen is required occasionally only, but in large quantities. Several years ago Dewar showed, as a lecture experiment, how coal-gas could be freed from methane and other hydrocarbons by cooling it to a sufficiently low temperature. Recently d'Arsonval (*Ann. Chim. et Phys.*, 1902 [7], vol. 26, p. 446) has proposed this as a method of obtaining hydrogen; the process has, however, not yet proved of any commercial value.

Experimental Plant.—In considering the type of apparatus suitable for experimental work, it must be borne in mind that the plant should be capable of producing gas at a comparatively high rate, at least for a limited number of hours. As will be more fully explained in describing the compressing plant, it is advisable to make the gas in sufficient quantities to supply the pump at its normal rate of working, which in our case was 100 to 130 cubic feet per hour. Under all conditions where the cost of a large capacity gasometer is not prohibitive, it would doubtless be more convenient to generate the gas slowly and continuously and then compress it, whenever the gasometer was filled. With such an arrangement it would have been more convenient even in the laboratory to use the electrolytic process.

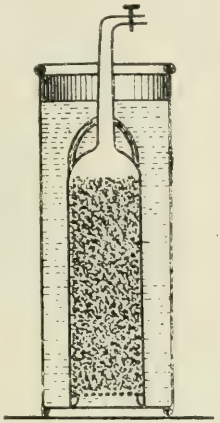


FIG. 2.—EXPERIMENTAL HYDROGEN GENERATOR, CONSTRUCTED THROUGHOUT OF LEAD. HEIGHT, 2 FT. 6 INS.; DIAMETER, 1 FT.

Preliminary experiments made in this direction showed that a satisfactory electrolytic cell could be easily and cheaply fitted up. This was effected by lining the sides of an ordinary stoneware mix-pan with sheet lead, and using as a cathode a spiral coil of lead tube, covered with an inverted bell jar. From the top of this the gas is drawn off. To equip a plant to make gas at the rate mentioned above was, however, too costly for a temporary outfit. The preparation from Brunner-Mond zinc and 20 per cent arsenic-free sulphuric acid was therefore resorted to, spelter of this quality being found to give gas of high purity. Sufficiently finely granulated zinc can be obtained by pouring molten metal into water from a height of about 3 feet. Three lead generators were used, of the ordinary type containing solid caustic soda, direct to the gasometer and compressor. Analysis proved the purity to be 98. per cent hydrogen.

Nitrogen: Commercial Manufacture and Applications.

Already at the present time nitrogen is coming into use in several of the cyanide processes, an application which will doubtless increase largely so soon as a satisfactory and economical method of generation has been devised. For, despite the apparent simplicity of the process, no very economical method of effecting the separation from the oxygen of the air is available. The older method of passing air over heated iron or copper is chiefly employed technically. In those cases where a large supply of nitrogen is needed, it would be advisable to carefully consider the employment of the waste gases from gas engines and sulphuric acid plants, which are available in quantity and contain a much reduced percentage of oxygen. It must also be borne in mind that similar gases are passed to waste in the course of manufacture of oxygen by Brin's process; whilst, provided any of the proposed methods of extraction of oxygen from liquid air by fractional distillation become of permanent commercial value, they will prove of direct assistance for the problem under consideration.

As will be seen below, pure nitrogen can be prepared at moderate cost by an adaptation of the Harcourt method (Lupton, *Chem. News*, 1876, vol. 33, p. 90; R. Marston, Eng. Pat. 19,074 of 1900), consisting in burning out the oxygen of the air by the hydrogen contained in ammonia. Finally, the laboratory process of generation from ammonium nitrite (K. T. Fischer and H. Alt, *Ann. der Phys.*, 1902 [4], vol. 9, p. 1149; von Knorre, *Chem. Ind.*, 1902, vol. 25, p. 531 and p. 550) is out of question for large scale working, owing to the prohibitive cost of material. At the recent International Chemical Congress, R. Knietsch (*Chem.-Zeit.*, 1903 [48], p. 586) proposed passing air and excess of hydrogen over warmed platinized asbestos; and at the same meeting a few details were given of

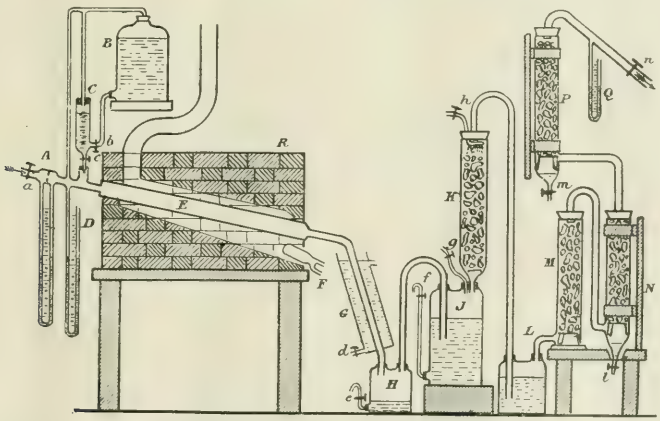


FIG. 3.—DIAGRAM OF NITROGEN PLANT.

a. Air-inlet tap from blower.
A. Gauge indicating rate of flow of air.
B. Reservoir of ammonia liquor.
C. Graduated tube for measuring rate of flow of ammonia.
b. Tap for filling tube C with ammonia.
c. Tap for regulating admission of ammonia.
E. Iron gas-pipe filled with copper turnings.
R. Furnace; built up of loose firebricks, and heated with large Fletcher furnace tuyere F.
G. Condenser with water inlet cock *d*.
H. Condensed ammonia receiver with draw-off *c*.
J. Water washer, through which water or acid could be passed, inlet cocks at *g* or *h*, outlet at *f*.
L. Acid washer.
M. Quartz tower scrubber.
N and P. Two caustic soda towers with draw-off cocks at *m* and *l*.
Q. Manometer.
n. Exit to gasometer and compressor.

the process of Messrs. Elkan, of Berlin, who supply the compressed gas in cylinders.

Experimental Plant.—From preliminary trials the Harcourt method seemed to be the only one which could be fitted up in a limited space with ordinary apparatus and suitable to produce gas at a moderate cost. The plant is shown in Fig. 3. An iron gas-pipe about 5 feet long and 2 inches internal diameter was filled with copper turnings, connections being made at one end for the introduction of air, supplied by a blower, and of the required quantity of ammonia liquor; at the other end to condensing, washing, and drying plant, and through these to the compressor. The method works without the slightest difficulty, provided that the rate of admission of air and ammonia is properly regulated. From the preliminary experiments it was found that unless the ammonia is always in considerable excess of that required theoretically, oxides of nitrogen are produced which cannot easily be removed. When gas containing such impurities is compressed, serious corrosion of the valves and cylinders of the pump occurs. On the other hand, if the excess of ammonia is not removed, similar difficulties are met with.

The method of working actually adopted was to admit approximately twice the theoretical amount of ammonia, and by passing a fairly rapid current of water through the washer J, such part of the ammonia as was not condensed in H was efficiently removed, the last traces of ammonia being held back by the sulphuric acid in L. To regulate the quantity of ammonia necessary, a rate gauge A was inserted in the air-supply pipe. This gauge was of a very simple construction, and consisted of a constriction in the supply tube each side of the construction being connected to one limb of a U-tube containing water, the difference in heights of which indicated the rate of flow of the gas. The instrument is calibrated, once for all, by taking observations with an ordinary gas meter or gasometer. The scale of the readings depends, of course, simply on the size of the constriction.

As an example, one of these gauges, having a constriction of about ⅛-inch bore, gave about 40 cms. difference of level for a rate of 60 cubic feet per hour. Knowing in this way the rate of flow of the air, the admission of ammonia liquor was regulated by means of the graduated tube, so as to supply about twice the theoretical amount. The method by which this was performed will be quite clear from the diagram. The gas obtained was entirely free from oxygen and oxides of nitrogen, but contained about 4 per cent hydrogen. This could, of course, be easily eliminated by passing through an additional tube of heated copper oxide, but for most purposes the presence of hydrogen would be of no disadvantage.

For the guidance of any one employing the method in this form, we might state that in one operation some 200 cubic feet were compressed, about 9 liters of 0.880 ammonia being passed through the apparatus; the flow of gas was regulated from time to time so as to supply the pump continuously at its normal rate of working. The cost of the ammonia for 1000 cubic feet of nitrogen would be about 17s. 6d. (about $4.20), or half this amount if the excess of ammonia is efficiently recovered.

Carbon Monoxide.

Experimental Plant.—For most chemical processes pure carbon monoxide is rarely required, some form of producer or water-gas being generally employed. Where, however, the pure gas is a necessity, the manufacture of formates by the recent synthetical Goldschmidt process renders it possible to obtain it at a reasonable cost and in an extremely simple manner. The actual apparatus used is shown in diagram (Fig. 4), and consists of a bolt-head E (9 liters) half filled with sulphuric acid (sp. gr. 1.73). The heating was performed either by an electric resistance furnace as represented, or by an ordinary gas furnace; the former is preferable, when working with combustible gases, where electric current is available.

An electric furnace of the kind can be built up temporarily at trifling cost. The outer walls are constructed of loose firebricks; the electrodes consist of two flat pieces of boiler plate, the space between which is filled with ground coke. An electric current passing through the coke heats this up to any desired temperature. In the present case the iron plates were each 11 inches square, the disance between them being 14 inches; the layer of coke G, about 40 pounds, being 7 inches deep. This gave a resistance when cold of 13 ohms and about 1.5 ohms when heated up to the working temperature. When generating gas at full rate, over 4 kw. are required to maintain the temperature.

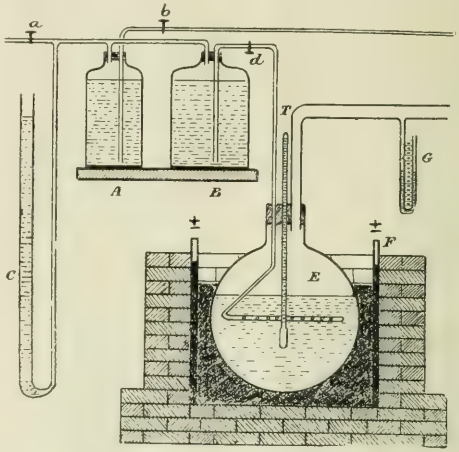


FIG. 4.—DIAGRAM OF CARBON MONOXIDE PLANT.

E. Bolt head containing boiling H_2SO_4.
T. Thermometer.
B. Reservoir for formic acid.
G. Gauge on main gas-pipe before washing apparatus.
F. Electric heating furnace.
a. Inlet cock from compressed air.
C. Tube acting as constant pressure valve, keeping a pressure equal to 2 or 3 ft. of water on upper surface of liquids in flasks A and B.
A. Reservoir of caustic soda solution connected with washing tower K (Fig. 3).
b. Regulating cock for same.

The reservoir B contains a supply of technical 90 per cent formic acid, from which the carbon monoxide is generated. This reservoir is kept slightly above atmospheric pressure by being connected to a supply of compressed air, thus enabling the acid to be easily forced over. The former acid is delivered below the surface of the boiling sulphuric acid in the bolthead, the flow being regulated by the cock *d*. The temperature which, when the formic acid is added, of course tends to fall, is maintained throughout the run at about 150° to 170° C. In this way, with a limited amount of sulphuric acid, the process can be run continuously.

The gas is purified in the apparatus shown in Fig. 3, the only modification being that the bottle L is in this case filled with 20 per cent caustic soda solution, and a similar solution is also allowed to drip into the quartz tower K (Fig. 3) from the supply bottle H (Fig. 4). Nearly the full theoretical yield of gas is obtained, about 133 pounds of 90 per cent formic acid being required per 1000 cubic feet, costing 50s. (about $12). The purity of the gas thus prepared was over 99 per cent.

Ethylene.

Experimental Plant.—Up to recent years ethylene has been used in considerable quantities in connection with the production of liquid air; the apparatus which we have already described for carbon monoxide can, without modification, be employed for this preparation. There is not, however, the same latitude with regard to temperature and rate of production as in the former case. It is essential that the sulphuric acid should be kept between 160° and 165° C., since, even at a few degrees above this, carbonization commences, accompanied by produc-

tion of sulphurous acid and carbon monoxide; at a temperature below 160° C., the yield falls very rapidly, almost all the alcohol being transformed into ether. The sulphuric acid used in the bolt-head should be of such dilution as to boil at 160° C. Methylated spirit admitted through a perforated lead tube (see Fig. 4). At first scarcely any ethylene is evolved, but as part of the water in the acid becomes displaced by the alcohol, the temperature being kept constant, the rate of production gradually increases, and, after about half an hour, becomes fairly steady.

A constant evolution of gas can be maintained under these conditions for any length of time, but the flow of gas is only about one-tenth of what the same sized apparatus would produce in the case of carbon monoxide. The yield obtained was not much more than half the theoretical. An addition of ferrous sulphate to the sulphuric acid has been proposed by R. N. Lennox as ensuring against carbonisation and evolution of sulphurous acid. This addition seems to be a considerable improvement on the original process. The acid mixture is made with concentrated sulphuric acid (sp. gr. 1.84) and sufficient saturated ferrous sulphate solution to bring the boiling point down to 160° C.

Another method proposed by G. T. Newth (*Jour. Chem. Soc.*, 1901, v. 79, p. 915), which consists in employing syrupy phosphoric acid in place of sulphuric acid, was tried in the same apparatus. The temperature should be kept between 200° and 220° C.; there is no carbonization, but a considerable amount of ether is collected. The yield in this case was even lower than with the sulphuric acid method, but the process can be worked quite continuously, and the quantity of phosphoric acid required is not large.

Various Other Gases.

The foregoing notes deal with the preparation of such gases as cannot easily be obtained commercially. With regard to many other gases similar methods could, of course, be adopted, but producing them on the scale with which we have been dealing would hardly repay the trouble involved, in those cases where they are already on the market. Further, for such gases as sulphuric acid, chlorine and ammonia, a special pump would be necessary; and even before oxygen could be compressed, much time would have to be spent in carefully removing all traces of organic matter from the pump cylinders, connections and gauges.

Oxygen, nitrous oxide, carbonic acid, sulphurous acid ammonia can readily be obtained from the various companies who make a specialty of their manufacture. Where a compressed gas is not required, oxygen in a similar way to acetylene can be produced by the action of water on one of its solid compounds. A French company has recently put on the market a mixture of sodium peroxide and bleaching powder, under the name of "Oxylith," which yields oxygen of satisfactory purity. The cost of the gas produced by this method (5s. 9d., or about $1.38 per 20 cubic feet) would, however, be prohibitive where a large quantity is required.

So far as acetylene is concerned, it will be recalled that, as a result of the exhaustive investigations which followed on numerous and disastrous accidents, Bethelot and Vielle showed that it is highly dangerous to compress this gas above four atmospheres. The gas, however, can now be stored in cylinders, filled with some porous material saturated with acetone, this liquid absorbing about 24 times its own volume of gas per atmosphere pressure (A. Janet, *Génie Civil*, 1903, 180).

In Germany (O. N. Witt, *Die Chemische Industrie des deutschen Reiches im Beginne des* 20 Jahrhunderts, pp. 100-105) considerable use has been made in recent years of liquid chlorine, which is produced by several companies, and notably by the Badische Anilin Company, and can be obtained retail (e. g., Kahlbaum, Berlin) for 1s. 6d. (36 cents) per pound in bombs of 20 pounds or over. Methyl chloride (2s., or 48 cents per pound, Douane, Paris), phosgene (Kahlbaum, 6s., or $1.44 per pound), and ethyl chloride (2s., or 48 cents per pound), can all be obtained commercially, and find uses, particularly in the color industries and for refrigeration.

Compression and Storage of Gases.

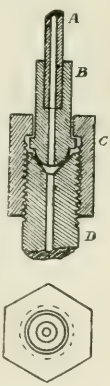
The portion of the subject which we have to deal with now is of rather a special nature. Much of the information given below will be well known to those few who have been connected with commercial gas-compression plants; but now that pumps can be obtained at a moderate cost and of sufficiently simple construction to give no trouble for continuous working, there is no reason why the great convenience of storing gas in the compressed state should not be more generally made use of. For work of this kind the smallest convenient plant comprises:

(1) A compressor capable of dealing with 60 to 130 cubic feet per hour, and of working up to 120 or 200 atmospheres.

(2) A small gas-holder (10 to 20 cubic feet capacity), which is used, not to store the gas, but to act as an equalizer between the pump and generating apparatus. It being assumed that, wherever possible the gas is made and pumped at the same rate.

(3) A stock of weldless steel gas cylinders.

As a general guidance with regard to cost, the price of the compressor may range from 60 *l.* to 100 *l.*, (about $290 to $485) and the gasometer from 10 *l.* to 20 *l.* (about $48.50 to $97). For most purposes it is convenient not to exceed the commercial pressure of 120 atmospheres. For this pressure, gas cylinders, ready fitted with valves, can be obtained at about 1s. (about 24 cents) per cubic foot of gas stored, when purchased in small quantities; or at half this price when bought on a larger scale. For higher pressures, the cylinders have to be made to order, and are correspondingly more expensive. Another 10 *l.* to 20 *l.* ($48.50 to $97) should be allowed for the purchase of two or three pressure-gauges, a dozen cone-connections, eight or ten high-pressure valves, and the capillary copper tubing which serves to conduct the gas from the compressor into the receivers.



A. Flexible copper tubing.

B. Cone.

C. Nut by which cone is pressed home. Screwed "½ in. gas."

D. Standard connection forming part of cylinders, valves, or compressor.

FIG. 5.—CONE CONNECTIONS.

Weldless copper tubing of ⅛ inch bore and ¼ inch external diameter is both strong and large enough for this purpose, and can be readily obtained from any copper tube manufacturers. This size has the further advantage, when annealed, of being quite flexible, and can thus be bent, whenever used, to the most convenient shape. The ends of each length of such tubing are soldered into brass or gunmetal cones, as shown in Fig. 5. These are screwed to the cylinder or pump valves by a nut which surrounds them. In a plant of this kind it is advisable to keep to a standard size, "half-inch gas" being most convenient for this purpose.

An ordinary air-pump is, of course, not suitable for dealing with combustible gases. The cylinders of the compressor should be entirely closed, the piston-rods passing through properly made stuffing boxes. The smaller compressors are usually of the tandem two-stage type, the low-pressure cylinder compressing to about 7 atmospheres, the gas being then passed through a cooling coil into the high-pressure cylinder, which forces it up to the full pressure. The high-pressure cylinder delivers its gas, through another copper coil immersed in a cooling tank, into a small gas cylinder, which serves to separate the water used to lubricate the pump. At the bottom of this separator is a valve for withdrawing the water.

If the pump is required to suck in its supply of gas under a partial vacuum, the low-pressure inlet valve should be arranged so as to be mechanically lifted at the top of each stroke. The water for lubricating the cylinders is fed through a sight feed, and for a compressor of the size we are dealing with, a single drop per two or three revolutions is an ample supply. The clearances should, in both cylinders, be about 1-32 inch, or at any rate not exceed 1-16 inch, in order that, at the highest working pressures, the pump may deliver its full volume and not merely compress and expand the same gas.

The following precautions are of the highest importance from the point of view of safe and satisfactory performance:

(1) The greatest care must be taken never to allow much more than the above-mentioned quantity of lubricating water to enter, as with such small clearances this water carried into the high-pressure cylinder would be unable to pass through the narrow outlet valve and would burst the cover or bend the crank-shaft.

(2) If the apparatus is to be used for air, or more especially for oxygen, it is of vital importance that no oil should be employed, either in the pump cylinders or in any of the valves, connections, or gauges. Many disastrous explosions have resulted from the neglect of these precautions. The water, may, however, if desired, be replaced for lubrication by glycerine, which forms an excellent substitute for oil for this purpose.

(3) Each time before running the pump, it is advisable to turn it through one or two revolutions by hand to ensure that it is working freely. If the gas to be pumped is combustible, before connecting to the gas holder the pump should be run for a minute or two, with the inlet cock closed, and the end of the delivery pipe placed under water. In this case, if the stuffing boxes and connections are satisfactorily tight, the pump will be running under a vacuum and should deliver absolutely no gas.

(4) The purity of any combustible gas must, of course, be properly ascertained, as any admixture with air would lead to serious explosions.

(5) It is very advisable to adopt the excellent system, employed by all the gas-compressing companies, of distinguishing between combustible and non-combustible gases, by invariably storing the former in cylinders characterized by a bright red color, and fitted with left-handed connections. Even where this is done it is advisable before connecting a partially filled cylinder with the pump to test its contents at a flame.

(6) All storage cylinders, connections, and other apparatus, with the exception of gauges should be occasionally tested hydraulically to double the maximum working pressure.

So far as the actual compressing is concerned, a clear idea will be obtained from the diagrammatic sketch (Fig. 6). The gas passes from the purifying apparatus shown in Fig. 3 to the gasometer A (Fig. 6), from which the two-stage compressor, driven by an electric motor, forces it into the water separator F. At its exit from this separator the gas is sufficiently dry for almost any purpose for which it may be required, since the percentage of aqueous vapor in a gas at 100 atmospheres is only 1-100 of its amount at ordinary pressure. When the gas is being made at the normal rate the valve *k* is kept open, the valve *m* closed, and the gas passed directly into a storage cylinder, such as L or K, or, in the case of our own work, direct into the pressure furnace M. These were situated in the room on the next floor of the building to the compressor.

A high pressure connection is also led direct to a duplicate gauge g_4, by which the pump pressure can be independently read. When necessary the gas can be blown off from the valves *q* on the upper floor, or *o* on the lower; *o* being connected to a pipe leading outside the building, for use with poisonous gases such as carbon monoxide. If, for any reason, the supply of gas falls below the normal rate, the valves *m* and *l* are partially opened, *n* being kept closed; a part of the gas delivered by the pump then returns to the gasometer, and is compressed again, thus avoiding the necessity of either stopping the pump or working it under a partial vacuum.

When dealing with gases which can only be conveniently prepared at a very slow rate, it is, of course, necessary to give up any idea of continuous pumping. In these cases the gasometer is allowed to fill slowly; the pump is then started, and stopped a few minutes afterwards, so soon as all the gas has been pumped. The storage cylinder is thus filled step by step up to a desired pressure. It is not possible to restart the pump against a high pressure; the gas contained in the water separator F must therefore be blown off, and since, at a high pressure, the volume thus returned to so small a gasometer would take up a large part of its capacity, it is preferable to employ an auxiliary cylinder G, which takes the major part of the contents of F, the residue only being returned to the gasometer by the valves *k*, *m* and *l*. The contents of G can be returned to the gasometer and pumped during the course of the next run through the valves *n* and *l*, *m* being kept closed. This last method of working is, of course, somewhat complicated, but has proved very useful in a few cases where it was practically impossible to produce the gas at the normal rate.

For those purposes where it is required to study some chemical reaction or to purify a gas when under high pressure, a gas cylinder with a removable cover is employed. The ordi-

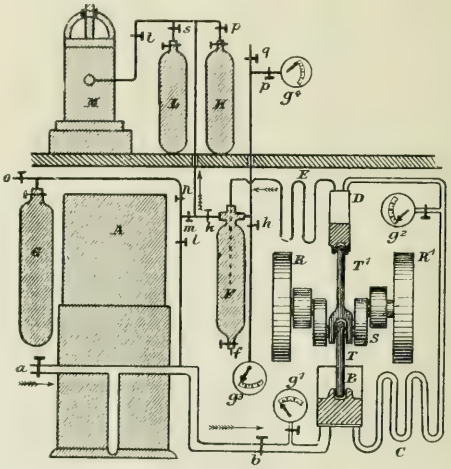


FIG. 6.—DIAGRAM OF COMPRESSING PLANT, GASOMETER, AND CONNECTIONS.

a. Inlet cock to gasometer from gas generating and purifying apparatus (see Fig. 3).
A. Gasometer (10 cb. ft. capacity).
b. Inlet cock to compressor.
g_1. Vacuum gauge on inlet to low-pressure cylinder.
B. Low-pressure cylinder.
C. Cooling coil for ditto.
g_2. Gauge showing pressure at exit from low-pressure cylinder.
D. High-pressure cylinder.
E. Cooling coil for ditto.
F. Water separator.
f. Water blow-off.
G. Gas cylinder used as auxiliary receiver.
g_3. Gauge on high-pressure outlet.
g_4. Duplicate high-pressure gauge.
K, L, M. Receivers for compressed gas.
q, *o*. Blow-off valves.
R, R¹. Pump fly-wheels.
S. Crank shaft.
T, T¹. Connecting and piston rods.

nary cone joint, as shown in Fig. 5, works satisfactorily to close the opening of any tube up to one-inch bore. Above this size it is necessary to resort to some form of spigot joint, such as is shown in Fig. 7. One or two turns of lead wire about the same diameter as the groove, are inserted in it, the ends of the lead being bevelled so as to overlap each other. The cover is then forced home by means of the bolts provided for the purpose, and, crushing the lead outwards and upwards, forms a gas-tight joint.

A. Cylinder containing solid reagent to dry or purify a gas under pressure, or react with it.

B. Cover.

D and D^1. Bolts.

E. Spigot and spigot groove (about $\frac{1}{8}$ inch wide for 2-in. bore, rising to $\frac{1}{4}$ or 5-16 in. for sizes up to 1 ft.)

The central part of the cover projects beyond the spigot, and is turned to nearly fit the bore of the cylinder. This acts as guide when putting on the cover, and protects the spigot itself from injury when the lid is off.

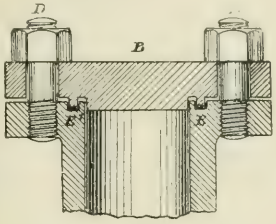


FIG. 7.—SPIGOT JOINT.

When making such a joint for the first time, exceptional care must be taken that the nuts are pulled down evenly, as otherwise the cover may be strained or, being out of true, the joint will not be gas-tight. When the cover has once been fitted correctly it can be removed and replaced some hundred times before it is necessary to add fresh lead packing. We have used joints of this kind up to a foot diameter, which have always worked satisfactorily. Above this diameter the weight of the cover and the size of bolts required become somewhat unmanageable when designed for pressures of 100 to 200 atmosphres.

In the discussion which followed the reading of this paper, and which is given in full in the *Journal of the Society of Chemical Industry*, February 15, p. 93, Mr. W. Thomson thought that the authors had not dealt sufficiently on the merits of the process, worked by the Industrial Engineering Company at Newton, near Hyde, as a comparatively large-scale laboratory method. It is one that may be easily carried out in the laboratory. Superheated steam is passed through iron turnings (heated to redness in a retort); the turnings become oxidized, liberating the hydrogen from the steam. Coal gas or producer gas can then be passed over the iron oxide, with a resulting deoxidation of the iron. Superheated steam is again passed over the reduced iron. He claimed that hydrogen could thus be obtained almost chemically pure at a cost of about 1s. (24 cents) per 1000 cubic feet.

In view of the large excess of ammonia, which the authors found necessary to use when producing nitrogen by means of Harcourt's process, it was suggested by Dr. Markel that this amount might be lessened if precautions are taken to eliminate the water vapor from the mixture of ammonia and air, entering the combustion tube.

Mr. Scudder had some years ago used steel cylinders for compressing water gas, and found that after a time the gas was contaminated with iron carbonyl, which rendered the compressed gas useless for illuminating and experimental purposes.

Mr. Hutton, in reply to Dr. Markel, said they had always employed double the required amount of ammonia in order to ensure against the presence of oxides of nitrogen; doubtless a smaller excess would be sufficient.

PRODUCER GAS AND WATER POWER

By Oskar Nagel, Ph. D.

Dr. Joseph W. Richards, in his presidential address, delivered at the third general meeting of the American Electrochemical Society in New York City, April 18, 1903, called attention to the fact that there are sources of surplus power distributed over a large part of the United States in a condition at present as undeveloped as was Niagara Falls' power when Columbus came to these shores. Dr. Richards is thereby referring to the surplus power from blast furnaces and gas producers, obtainable by using gas engines.

There is no doubt that near coal mines producer gas power can be produced at about the power price of Niagara Falls, and by using blast furnace gas, power can be obtained even considerably cheaper, so that in the near future the blast furnace will be of the same importance as a gas producer as it is at present as iron producer.

A 20,000-hp. plant for blast furnace gas, completely erected, including building and gas purifying plant, will cost about one million one hundred thousand dollars ($1,100,000) and the cost of a horse-power for 24 hours in such a plant will be 3½ to 4 cents as compared with 5 cents for the lowest cost at Niagara Flls. This will enable the iron works also to sell power at a low price, and to make the blast furnaces great central power plants comparable to the water-power resources of nature.

For every ton of iron 45,000 cubic meters of gas are obtained, 50 per cent of which are used for heating the cowpers. There is, therefore, a surplus of 22,500 cubic meters for every ton of iron, corresponding to 7000 hp. hours.

The main point to be considered in estimating the cost of a producer gas power plant is the cost of coal, of which 1 to 1½ pounds are required to develop 1 hp. hour.

Below are given the prices for power, figured on coal prices of 80 cents, 90 cents, $1.00 and $1.50 per net ton. They will show that it is only a matter of future development that the coal-mining districts will become great power stations of the world, and will be even more advantageous to certain industries than water power.

A 1000-hp. producer gas plant completely erected, including engine, will cost about $66,000; figuring depreciation, interest and working expenses with coal price of 80 cents per ton, 1 hp. for 24 hours will cost, for such a plant, 5.19 cents. Figuring coal at 90 cents per ton 1 hp. for 24 hours will cost 5.37 cents. Figuring coal at $1.00 per ton, 1 hp. for 24 hours will cost 5.55 cents, and figuring $1.50 per ton for coal, 1 hp. for 24 hours will cost 6.45 cents.

These results compare favorably with the lowest price at Niagara Falls, that is, 5 cents per hp. in 24 hours.

Following are given the average price per short ton of coal in the United States for ten years:

	Anthracite.	Bituminous.
1892	$1.57	$0.99
1893	1.59	0.96
1894	1.51	0.9
1895	1.41	0.86
1896	1.50	0.83
1897	1.51	0.81
1898	1.41	0.80
1899	1.46	0.87
1900	1.47	1.04
1901	1.67	1.04

THE PRODUCTION OF PURE METALS FREE FROM CARBON BY THE ALUMINOTHERMIC METHOD.

By Hans Goldschmidt, Ph.D.

In the issue of November, 1903, of Electrochemical Industry, a complete review of the manifold industrial applications of aluminothermics was given by the author. The following notes are intended to give some supplementary information on the production of pure metals by the aluminothermic method, and on the uses of such metals in metallurgy. As noticed in our former article, it was for the purpose of preparing

pure refractory metals, free from carbon, that the aluminothermic reaction was first made use of. While at first sight it might appear that no special extended practical development was required for a reaction of such apparent simplicity as the reduction of metallic oxides by aluminium, yet it is a fact that in the case of every metal much experimental work had to be done in order to obtain pure metals of uniform quality and with a high efficiency, so as to satisfy commercial requirements.

The aluminothermic preparation of the metals and alloys —especially chromium and manganese—as carried out now on a large commercial scale, takes place in a sort of crucible in which several hundred kilograms of metal are reduced in a single operation. On account of the great rapidity of reaction, this operation is completed in scarcely thirty minutes. The principle of the preparation of the mixture is, of course, to use equivalent quantities of the oxide and aluminium. In practice, however, the great facility with which aluminium alloys itself makes it advisable to use somewhat more of the oxide and less of the aluminium than would correspond to a mixture in equivalent proportions. The object is to oxidize all the aluminium during the reaction and to produce the metals free from aluminium. Solely by a suitable choice of the proportions of the mixture is it possible to regulate the reaction so as to get no aluminium in the reduced metal. This will surprise the experienced metallurgist in view of the great tendency of aluminium to alloy with the pure metals, and in view of the known fact that it is impossible to get metals free from carbon by means of reduction with carbon, even if a considerably larger amount of oxide is used than is equivalent to the carbon used for the reduction.

CHROMIUM.

Chromium, fused, free from carbon, with a purity of 98 to 99 per cent, can at present only be produced by the aluminothermic reaction. The metal, thus prepared, contains as impurities traces of iron and silicon. It is a brittle metal and remains bright indefinitely; its melting point is higher than that of platinum.

Pure chromium alloys with liquid steel. Its use allows the production of steels with a high content of chromium and with less carbon than is possible with the use of ferrochromium. The latter mostly contains carbon to the extent of 8 to 12 per cent of the chromium. The presence of this carbon makes it impossible to use ferrochromium for the production of steels with a high content of chromium and a comparatively low content of carbon. On the other hand, chromium free from carbon, as prepared by the aluminothermic method, is of great uniformity of composition. Faulty and unexpected fusions, which frequently occur in using ferrochromium on account of irregularities in the carbon content, will be avoided by employing pure chromium.

The addition of chromium to the charge in the Martin furnace can only be made at the end of the operation, and care must be taken to avoid the simultaneous introduction of injurious elements into the steel. Therefore, the less of the latter there are in the steel the better will be the quality of the steel. While with ferrochromium, even of a high grade, the loss through combustion reaches 20 to 25 per cent, the corresponding loss is much smaller if pure chromium is used.

Pure chromium is of the greatest practical value for the production of crucible steel. It is used for manufacturing guns, projectiles, and particularly for tool steels containing 5 to 10 per cent of chromium, 5 to 10 per cent tungsten, and not more than 0.6 to 0.7 per cent of carbon.

MANGANESE.

Manganese, made by the aluminothermic method, is free from carbon and practically free from iron. Its purity is about 99 per cent. It resists atmospheric influences for an unlimited period, while the manganese which is made in crucibles by reduction with carbon, crumbles when in contact with air. Pure manganese is very brittle, and can be easily crushed with the hammer. In the fracture it often shows beautiful rainbow colors. One of its special features is the ease with which it alloys with copper, nickel, zinc, tin, aluminium and also with chromium, titanium and boron. The fusing point of manganese is considerably below that of chromium; by the careful investigations of Heraeus it has been found to be at 1245 deg. C. (2241 deg. F.)

Pure manganese is used for the manufacture of very hard *steel* which contains 12 to 14 per cent of manganese, especially for making steel bolts which are exposed to very heavy strain, for instance, in dredges, etc. It is, however, in the *copper*, *brass* and *nickel* industries that the great advantages of the use of pure manganese and its alloys are most apparent. Pure manganese may be added in any percentage to *zinc-copper* alloys, the result being a very essential increase of strength and density and often, also, of elasticity. Such alloys can also be rolled more easily.

Manganese should not be added to alloys of *tin and copper*, containing more than about 2 or 3 per cent of tin, as the quality of the material is thereby deteriorated. But if the content of tin is held within certain limits, manganese may be added to good advantage.

For *nickel* castings manganese is used as a de-oxidizing agent, to produce a greater density. In this case 2 per cent of manganese is added to the molten nickel. This is more advantageous than an addition of magnesium, for the reason that magnesium, if added in excess, has a bad effect; there is no such danger with manganese. In mints manganese is added to the copper-nickel alloys (25 to 75), from which the nickel coins are made; the addition of manganese amounts in this case to about 2 per cent.

Manganese is also used with good results for making *German silver* and *nickel* alloys; when added to the former in small amounts, a bright color is produced, similar to that of silver. For *aluminium* alloys an addition of manganese-copper, *free from iron*, is preferable to nickel or zinc additions. If the manganese-copper is added to the amount of 3 per cent, the strength of the material is increased, denser castings are obtained, and the alloy can be more easily machined; moreover, the cost is lower than an addition of nickel.

Copper and *bronze* castings lose their brittleness if manganese is added instead of phosphorus; a material is thus obtained in which threads may be easily cut. Manganese-copper alloys are made to a large extent, containing from 2 to 12 per cent of manganese. Bronzes with 5 to 6 per cent of manganese have about the same color as copper, and are very fire-resisting; they are, therefore, used especially in the fire-boxes of locomotives. Sometimes about ½ per cent of nickel is added to such a copper-manganese alloy. For the preparation of manganese-copper alloys it is always preferable to first melt alloys *with a high content of manganese*—for instance, 70 per cent of copper and 30 per cent of manganese.

If ferromanganese is used, even of the best quality (about 80 per cent of manganese, 8 to 9 per cent of iron, the balance being carbon and traces of other elements), iron is always introduced into the copper. The elasticity of the alloy and its fire-resisting qualities are thereby diminished, as is shown by extensive comparative tests. The ordinary copper-manganese will, therefore, contain always 2.5 to 4 per per cent of iron for 25 to 30 per cent of manganese.

Pure managanese easily alloys with the copper, with very small loss. This represents another advantage over ferromanganese. The higher price of pure managanese is counterbalanced by the uniformity and improved quality of the castings. These can only be obtained by the use of pure manganese. Such castings are, of course, made from the best electrolytic copper.

In these alloys manganese fulfills two purposes. First, it

is a de-oxidizing agent. In general, an addition of about ¼ per cent of manganese is sufficient. Compared with other de-oxidizing agents, like phosphorus, manganese has the great advantage that if a surplus quantity is added, it improves the quality of the bath (the only exception being the case of bronze rich in tin). If too much phosphorus is added, it impairs the quality of the bath. In some cases, besides phosphorus, about 1 per cent of manganese is added.

Secondly, manganese is used to a large extent to improve the qualities of a great many metallic alloys. It combines easily with and has a great affinity to oxygen. Moreover, since manganous oxide slags are very fluid and have a low specific gravity, they easily and quickly separate out of the baths.

The practical applications of manganese are based on the principles just given. Manganese, either in the form of the pure metal, or, what is better, in the form of a high-percentage manganese alloy, is added in pieces of hazel-nut size to the molten metal bath in the crucible which is still in the furnace; after thorough stirring, the crucible is left for a certain time in the furnace at a steady temperature. The manganese slags then separate. Before adding the manganese the copper slags must be carefully removed.

All castings with manganese alloys are to be made under exclusion of air as far as possible. It is, therefore, useful to sprinkle a small quantity of borax upon the surface of the metallic bath in the crucible. It then forms a thick plastic slag.

High-percentage *manganese-copper* alloys are made by first melting the copper in a graphite crucible. Manganese, in the size of hazel nuts, is then added gradually by portions of 10 to 20 pounds, and the bath is thoroughly stirred. Before adding the manganese, the copper slag has to be removed. The metal must be repeatedly stirred, and after 5 to 10 minutes' interval the next portion of manganese is added until the whole charge is complete. If the bath contains an alloy of only 20 per cent of manganese it must be heated for an hour; in the case of an alloy of 30 to 50 per cent, heating for an hour and a half is necessary. The bath must be stirred at intervals. It takes altogether 2 to 3 hours to complete a crucible charge of 20 to 30 per cent manganese-copper.

High-percentage manganese alloy is best cast in the form of thin flat rods which can then be cut into narrower strips. In this form they are more easily used for the preparation of other alloys. However, it is still better to pour the original alloy into water, so that it assumes a granulated form. The small pieces thus formed—often hollow globules—facilitate the preparation of new alloys. For a 100-lbs. charge of 30-per-cent manganese-copper 75 pounds of copper and 32 lbs. of manganese are required. The loss is therefore small. The waste of the preceding charge is placed in the crucible containing the fluid copper. Before adding the manganese the resulting highly-fluid slag must be removed.

Manganese alloys with tin and zinc can also easily be prepared; generally the following proportions are used: Twenty parts of manganese to 80 of zinc, free from lead; 50 parts of manganese to 50 parts of tin, free from lead. The slag formed on the molten tin and zinc must, of course, be removed before adding the manganese, and the charge is kept heated for a couple of hours. With zinc it is important to take care that the temperature remains constant and does not increase. The loss in the preparation of 20-per-cent manganese-zinc is only 4 per cent.

An alloy of 30 per cent chromium and 70 per cent manganese is used, to prepare what is called *chromium-manganin*. It is used for the production of copper, containing chromium. Chromium-copper, containing 10 per cent of chromium, is also made by the aluminothermic method. Chromium-manganin alloys with copper as easily as pure manganese. Chromium seems to increase the elasticity of copper, while iron does not act in the same way.

Titanium may also be easily alloyed with manganese. This alloy is put on the market as *manganese-titanium* containing 30 to 35 per cent of titanium. It is also used for the manufacture of copper alloys. In the same way *manganese-boron*, containing 20 per cent of boron, may be used.

Other Metals and Alloys.

The aluminothermic reaction has also been applied in the preparation of *ferro-titanium*, which is used as a means of introducing titanium into steel. Other pure metals, free from carbon, have also been prepared by the same method, especially *iron, copper, tin, lead, nickel, cobalt, niobium;* while vanadium is produced, as Hittorf has shown, in form of V_2O, which looks entirely like a metal.

Like chromium, fused *molybdenum* is now produced in fused state by the aluminothermic reaction. It is a metal of gray color, like steel, and has a dense structure. It contains as chief impurity about 1 or 2 per cent of iron besides very small quantities of silicon, so that its purity is 98 to 99 per cent. Molybdenum is also applied in the first place for making toolsteel, and is often used as a substitute for tungsten. Molybdenum has the property of rendering the toolsteel specially hard. The percentage in which molybdenum is used for such purposes, is much smaller than that of tungsten. Moreover, it is much easier to harden molybdenum steel than tungsten steel.

In most cases, besides the addition of molybdenum, a high percentage of chromium, free from carbon, is also added.

The great disadvantage of the ordinary commercial molybdenum in powdered form is that this powdered metal is always somewhat oxidized, and that these oxides impair considerably the quality of molybdenum-steel, and in many cases even spoil it. The fused molybdenum which is made by the aluminothermic reaction is absolutely free from oxide, so that the disadvantages just mentioned are absent, if the pure metal is used.

Since, as already stated, molybdenum is mostly used in conjunction with chromium, an alloy of *chromium and molybdenum* has been prepared by the aluminothermic process, and the use of this alloy may be preferable in many cases. This alloy contains equal quantities of molybdenum and chromium. Like all other metals and alloys made by the aluminothermic process, molybdenum is free from carbon. The latest alloy produced in this line is an alloy of 75 per cent of *molybdenum*, with 25 per cent *nickel*.

Finally, for ballistic purposes, a *nickel-tungsten* alloy calls for special notice on account of its high specific gravity (which is 14.5) combined with great strength. It is easily machined, nevertheless.

Union Engineering Building. In a letter of March 14, addressed to the American Society of Mechanical Engineers, the American Institute of Mining Engineers, the American Institute of Electrical Engineers, and the Engineers' Club of New York, Mr. Andrew Carnegie has donated $1,500,000 for the Union Engineering Building. The total amount involved is not less than $2,500,000, for, in addition to the amount given by Mr. Carnegie, a sum of over $500,000, represents the investment in land for the three societies on West Thirty-ninth Street, between Fifth and Sixth Avenues; while the Engineers' Club has also acquired valuable land for its own purposes on West Fortieth Street, immediately facing the New York Public Library. The Union Engineering Building will probably be twelve stories in height. The three national engineering societies made trustees by Mr. Carnegie will have large headquarters there; and already several kindred bodies have made urgent requests for accommodation. There will be four or five auditoriums of different size, notably one to set 1200 to 1500 persons. Above all, there will be an engineering museum and a noble library hall, where all the libraries concerned will be grouped and consolidated, yet each section administered by its respective Society librarian, and each adding to its own specific literature, so as to avoid duplication of outlay for books or periodicals.

PHILADELPHIA SECTION MEETING OF THE AMERICAN ELECTROCHEMICAL SOCIETY.

The second meeting of this section was held on Friday evening, March 4th, in the assembly hall of the Engineer's Club. On account of the enforced absence of the secretary, who was ill, the election of permanent officers and adoption of proposed regulations and by-laws was postponed until the next meeting of the section. Mr. Carl Hering presided and Mr. C. J. Reed acted as secretary pro tem.

Storage Battery Invention.

Mr. Pedro G. Salom described some "Recent Experiments in Storage Batteries." Mr. Salom is the inventor and operator of the Salom electrolytic process for producing spongy lead from galena (for description see Electrochemical Industry, Vol. I., pp. 18, 488, 494), and has attempted to use this sponge, compressed, as the electrodes of a storage battery. When the sponge is compressed so as to be coherent, and yet not as solid as rolled lead, it makes a good negative electrode, but the positive electrode has so far not worked successfully, either because of the quality of the sponge or the mechanical construction of the plate. Mr. Salom has made a refined sponge. by using his ordinary sponge as anode in an acetate solution, and depositing on the cathode an exceedingly fine, voluminous sponge, which is practically chemically pure lead, and so finely divided that it compresses nearly 100 into one. This clean sponge was then compressed by tamping it down wet with a maul into holes in a quarter-inch lead plate, producing buttons of exactly the same size as the buttons of a Manchester plate. The specific gravity of the buttons is 10.37, against that of rolled lead, 11.37. The diameter of the buttons is one inch.

The plate thus made was subjected to very severe treatment, being charged with one-half ampere per button for one hour, and discharged in one hour, the operation being repeated perhaps 100 times on the plate shown. With this rate of charge and discharge the buttons always retained their metallic core, while converted superficially into peroxide.

In the discussion Mr. Carl Hering remarked that the tamping down would produce layers in the button, which would afterwards separate and shorten its life. Mr. Salom explained that this was avoided by compressing at once sufficient lead to make the button, and not by tamping down successive portions. Dr. N. S. Keith stated that he had made buttons from spongy electrolytic lead in 1882, which were as solid as lead itself, but that he had not thought of using them in a storage battery. Mr. Hering stated that a certain porosity was desirable, so that discharge could be rapid, since it is the time necessary for the diffusion of acid into and out of the plate which affects the rapidity of discharge. Mr. Salom replied that the prime necessity is a plate whose material will not wash off mechanically, and hence that the greater the density of the compressed sponge, the better. Dr. R. Gahl explained that there was a limit to the porosity obtainable; that the plate must have mechanical strength, and hence a limit is set to its porosity and the rate at which it can discharge. Mr. Salom explained that he had not been attempting to get a plate of high capacity, but had tried to reach the capacity of the Manchester plate, which he considered to be the best plate yet made for central station work. He had not considered it desirable to attempt to reach high capacity by use of highly porous buttons. Mr. E. W. Smith confirmed this view, stating that the high capacity once attained in the chloride accumulator by the use of zinc chloride in the buttons, had been accompanied by a sacrifice of strength in the buttons. A controversy here arose as to when a plate expands, Messrs. Salom and Reed stating it as their experience that the plates buckle while being charged; Messrs. Hering and Smith were equally positive that the plates swell on discharging. No agreement was reached on this point. Mr. Salom closed the discussion by a number of statements, to the effect that he had aimed to get one-sixteenth inch of the lead buttons converted into peroxide; that he had given the plate 100 or 150 charges and discharges, that the capacity had at first increased, and then kept constant; that he had kept a plate charged only over night, but that it stood well that long. The fineness of the refined sponge is shown by the fact that it can be "rotted" by the use of air, steam and acetic acid, and converted into white lead, in less than four hours, while the same process takes 3 to 5 days by the Bailey process (Mr. Zeller corrected this by naming one day) and 105 days by the Dutch white lead process.

Thermochemistry of the Dissociation Theory.

Mr. C. J. Reed read a communication on "The Thermochemistry of the Theory of Electrolytic Dissociation," which was identical with the paper read at the meeting of the New York Section (see p. 65 of our February issue). Dr. J. W. Richards replied to the criticisms of Mr. Reed; Dr. Gahl and Mr. Jackson considered that the theory of electrolytic dissociation was proved rather than dispersed by the calculations of Dr. Richards, which Mr. Reed criticised.

On account of the lateness of the hour, the paper of Mr. Carl Hering on "Some Constants of Use in Electrochemistry" was deferred until the next meeting of the section.

PRELIMINARY PROGRAMME OF THE ANNUAL MEETING OF THE SOCIETY OF CHEMICAL INDUSTRY.

The annual meeting of the Society of Chemical Industry for 1904 will be held in New York City on September 8 to 10. The president, Sir William Ramsay, will deliver the presidential address at the general meeting on Thursday, September 8th, at Havemeyer Hall, Columbia University.

Mr. William H. Nichols, the president of the General Chemical Company, and of the Nichols Chemical Camopany, has become nominated by the council of the society to succeed Prof. Ramsay. For the second time in the history of the society an American will be elected its president. The first to enjoy this honor was Prof. Charles F. Chandler, of Columbia University, as a representative of chemical science in America, the second one is Mr. William H. Nichols, representing chemical industry in America.

The annual meeting will last three days, from Thursday, September 8th, to Saturday, September 10th. The provisional programme is as follows:

Wednesday, September 7th, at 9 P. M., at the Chemist's Club: Informal reception.

Thursday, September 8th, at Columbia University: 10 A. M., council meeting. 10.30 A. M. general meeting; address by Sir William Ramsay. 1.00 P. M., informal luncheon at a place to be announced later. 2.30 P. M., seeing New York by stages and automobiles. 7.30 P. M., annual dinner.

Friday, September 9th: Visits to manufacturing establishments. 8.30 P. M., roof garden entertainment.

Saturday, September 10th: Visits to Manufacturing establishments. 8.30 P. M., smoker at one of the New York Clubs.

Sunday, September 11th: Excursion by steamer around New York, the Sound, and up the Hudson.

It is expected that the following works will admit the guests of the society: Bethlehem Steel Co., Alpha Cement Works, Nichols Chemical Co., New York Glucose Co., Standard Oil Works at Bayonne, N. J., Consolidated Gas Co., Sugar Refining Works of Arbuckel Brothers, American Sugar Refining Co. Federal Sugar Fefining Co., Pacific Borax Co., Sherwin-Williams Paint Co., Brewing plants of George Ehret, Jacob Ruppert, Lion Brewery; Lalance & Grosjean Enameled Ware Co., Marx & Rawolle Glycerine Works, United States Assay Office, Subway Power House (electrical equipment).

Following the meeting in New York the foreign guests will be taken on a tour through the country, the itinerary of which is the following: September 12th, Philadelphia, Pa.; 13th and

14th, Washington, D. C.; 15th to 17th, Pittsburg, Pa.; 18th to 22d, St. Louis, Mo.; 23d to 25th, Chicago, Ill.; 26th, Detroit, Mich.; 27th and 28th, Buffalo and Niagara Falls; 29th, Boston, Mass.; 30th, Boston or New York.

The date for the meeting, and for the tour has been selected by the society with the object in view of affording the members an opportunity to attend the International Congress in St. Louis during the week beginning Monday, September 19th.

If, as is very likely, the President of the United States will not be in Washington at the time of the visit there, it is hoped that a reception will be arranged for the visitors by President Roosevelt at Oyster Bay during the steamer excursion around New York, and, if necessary, changes of dates will be made to make this reception possible.

The following English committee has been appointed by the president to make the necessarly arrangements for the New York meeting:

Sir William Ramsay, Samuel Hall, Esq., Dr. E. B. Power, Dr. Boverton Redwood, Thomas Tyrer, Esq., H. Hemingway, Esq., R. W. Greeff, T. J. Wrampelmeier.

The New York Committee has been subdivided as follows:

Executive committtee: H. Schweitzer, chairman; T. J. Parker, secretary; R. C. Woodcock, treasurer; Virgil Coblentz and E. G. Love.

Committee of finance: William H. Nichols, chairman; Charles F. Chandler, H. A. Metz, T. J. Parker, R. C. Woodcock.

Hotel and transportation: C. B. Zabriskie, chairman; Leo Baekeland, DeLaguel Haigh, William F. Hoffmann, Clifford Richardson.

Entertainment and programme: E. G. Love, chairman; Leo. Baekeland, Marston T. Bogert, Gustav Drobegg, A. P. Hallock, G. C. Stone, Maximilian Toch. Invitation and press committee: E. J. Lederle, chairman; W. F. Fuerst, R. W. Moore, William J Schieffelin, R. C. Schuepphaus, H. W. Wiley, D. Woodman. Reception committee: Virgil Coblentz, chairman; H. C. Aspinwall, A. C. Bedford, F. J. Butterworth, W. B. Cogswell, Thomas A. Edison, William H. Erhart, H. C. Grant, Edward Hart, J. Hasslacher, A. C. Humphreys, E. J. Lederle, William McMurtrie, William H. Nichols, Charles Pellew, William J. Schieffelin, F. Schniewind, F. M. Smith, I. F. Stone, Louis I. Waldman, F. G. Zinsser.

A ladies' committee, the chairman of which is Mrs. Charles E. Pellew, will arrange for the entertainment and comfort of ladies accompanying our guests while in New York, and similar committees will be formed in the other cities to be visited.

Local committees have been appointed at the following cities to make the necessary arrangements during the tour: Philadelphia, William Weightman, Hon. chairman; Samuel P. Sadtler, chairman: Washington, H. W. Wiley, chairman; Pittsburg, K. F. Stahl, chairman; St. Louis, F. W. Frerichs, chairman; Chicago, T. B. Wagner, chairman; Buffalo and Niagara Falls, Charles E. Acker, chairman; Boston, Godfrey L. Cabot, chairman.

The New York annual meeting of the Society of Chemical Industry is the first one to be held outside of Great Britain, and it is the ambition of the American members of the Society to make it a memorable one.

It is stated that the funds which have most liberally been donated for this purpose, already amount to not very much less than $20,000.

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By George P. Scholl, Ph. D.

Electric Furnaces and Furnace Products.

Electrical Manufacture of Iron Alloys.—Gustave Gin, Paris, France. Patent 753,875, March 8, 1904. Application filed July 7, 1902.

The invention relates to the production of ferrosilicon and ferromanganese, and the first step of the process outlined by the inventor consists in the formation of an alkali or alkaline earth silicate. When using barium sulphate, he introduces a mixture of broken quartz or non-clayey sand, barium sulphate and charcoal into an electric furnace, in the proportions determined by the equation $SiO_2 + BaSO_4 + C = BaSiO_3 + SO_2 + CO$. In order to prevent vaporization of a too great proportion of the barium sulphate by a too high temperature, the expenditure of energy is stated to be limited to between 40 and 50 watts per square centimeter of transverse section of the electrode. The barium silicate thus obtained is reduced in a second electric furnace, after being mixed with oxide of iron or wrought or cast iron in proportions varying with the amount of iron in the desired alloy. A quantity of carbon is added, regulated according to the quantity of oxygen to be eliminated, but not enough to reduce the barium sulphate to sulphide. For instance, in order to obtain ferrosilicon with about 20 per cent of silicon, the mixture is made according to the formula $BaSiO_3 + Fe_2O_3 + 5C = Fe_2Si + BaO + 5CO$, or when using metallic iron, $BaSiO_3 + 2Fe + 2C = Fe_2Si + BaO + 2CO$. It is stated that this operation is readily effected with a current of between 25 and 35 volts, the expenditure of energy being between 50 and 60 watts per square centimeter section of the electrode. Under these conditions only an insignificant quantity of carbide of barium is said to be produced, while the volatilization of the barium oxide is not great. The furnace gases are led into a condensation chamber to recover the volatile substances. The production of ferromanganese is described as follows: "If it is desired to produce it at the same time as the baryta, one introduces into a convenient electric furnace a mixture of dioxide of manganese and sulphate of barium in such a manner as to produce the oxide mangano-barium according to the following formula: $MnO_2 + BaSO_4 + 2C = MnO, BaO + SO_2 + 2CO$. One thus realizes the electrical reduction as explained and according to the formula $3MnO, BaO + 4C = Mn_3C + 3 BaO + 3CO$. If one has in view the production of oxide of sodium or an analogous volatile oxide in an electric furance, one can carry out the first operation in a muffle furnace having a magnesia body and by substituting for the sulphate the corresponding sulphide according to the equation: $9MnO_2 + Na_2S = 3Mn_3O_4 + 2Na_2O + 2SO_2$. The electrical reduction is effected according to the following formula: $3Mn_3O_4 + 2Na_2O + 17C = 3Mn_3C + 2Na_2O + 14CO$. When it is desired to produce an iron alloy at the same time as the oxide of sodium, this oxide is volatilized in an electric furnace and can be collected by sublimation in a dust chamber, or by means of steam." The apparatus used by the inventor is illustrated in Fig. 1. A is the electric furnace in which reduction takes place. The sulphurous gases pass into a cooling apparatus B, whence they enter a chamber C, where they are dissolved in cold water injected through an atomizer. Pump D then passes the solution into apparatus B, where it passes through a mass of coke into which hot air is forced. "Under the simultaneous action of the furnace heat and injected air a mixture of air and sulphurous anhydride is disengaged from the solution and passes into the chamber E,

where it is dried by contact with the sulphuric acid. It is then passed into an apparatus F, adapted to change the temperature, in which it is heated by contact with the oxidated gases coming from the catalytic apparatus G. It passes subsequently into the latter apparatus, where the sulphurous anhydride is formed into sulphuric anhydride, which is collected in a suitable condenser, indicated in the drawing at HH."

Electric Furnace.—Charles Albert Keller, Paris, France. Patent 754,656, March 15, 1904. Application filed January 17, 1902.

The furnace is illustrated in vertical and horizontal cross-section in Fig. 2. It is intended to work in conjunction with

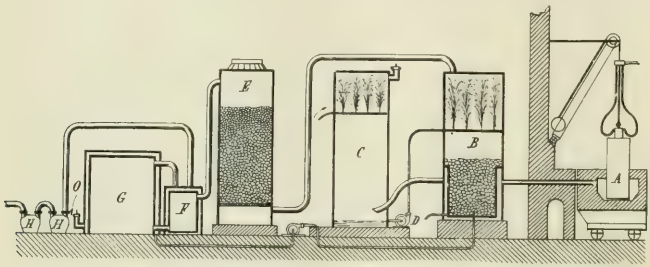


FIG. 1.—MANUFACTURE OF IRON ALLOYS.

a second furnace, which is to serve exclusively for the refining of the metal produced in the first furnace. Only the construction of the latter is described in the specification, it being stated that "any suitable electric furnace might be employed for refining, as may be convenient; but that which defines the peculiarity of this furnace in the present invention is the exclusive use of its capacity as a receptacle for metal prepared in a continuous manner in the upper furnace." The upper furnace is provided with a charging apparatus, and its upper part is constructed as a shaft furnace. Four vertical electrodes, A, B, C, D are located at the four corners of a square, and dip into a refractory vessel E, which constitutes the fusion chamber. Means are shown by which the electrodes can be vertically adjusted. The electrodes A and B are connected in parallel with one electric pole and the two other electrodes C and D, with the other pole. An arc is thus created at four points in the furnace, and four ampere meters K, arranged in the circuits connecting the electrodes, permit equalization of the intensity of the current at these four points. Two voltmeters L permit regulation of the voltage between the electrodes A and C and B and D. The tapping hole of the upper furnace discharges the metal through suitable conduits upon the base of the lower furnace. With the disposition of the electrodes as above, the operation is said to be continuous, as one of the four electrodes may be easily replaced during the operation without stopping the apparatus. During this replacement the total current passes through the other pair of electrodes.

Electrolytic Production of Metals and Compounds.

Process of Preparing Electrodes.—G. J. Atkins, Tottenham, England. Patent 754,114, March 8, 1904. Application filed October 6, 1903.

In order to prevent the disintegration of carbon electrodes, the inventor saturates them with oxidizable oil, such as linseed or cotton-seed oil. In some cases he mixes lamp black or any other finely divided carbon with the oil, before saturating the electrode material with it, whereby, he claims, the conductivity of the mass is improved and disintegration still more effectually prevented. The saturation of the electrode with oil is effected by placing it into a bath of the oil and letting it absorb as much as it will. After removal from the oil bath, the electrode is preferably allowed to stand for a time, in order to allow the oil to oxidize more or less, and is then placed in the electrolytic cell. It is claimed that the oil fills up the interstices between the particles of carbon, and does not interfere materially with the conductivity of the carbon mass, as it only fills up spaces which do not act as conductors; after the mass is saturated, the oil gradually oxidizes, especially after the saturated electrode is put to work in a cell, and it thus forms an insoluble material, which is unattackable by the electrolyte and will not melt and run away from the electrode, when the latter becomes heated in the course of the electrolytic operation. Paraffine, beeswax and other fatty matters used for this purpose are claimed to be inferior for the latter reason.

Electrode.—G. J. Atkins, Tottenham, England. Patent 753,819, March 1, 1904. Application filed April 8, 1903.

The invention relates to the treatment of carbon electrodes, so as to insure an even or uniform introduction of the current to the entire mass of the electrode. The conductor, intended to deliver the current to the carbon, is made of a sheet of metal, *e. g.* lead or copper. In order to prevent the electrolyte from gaining access to this conducting plate and destroying it, there is interposed between the carbon electrode proper and the conducting plate a layer composed of finely divided carbon that has been combined with non-oxidizable oil, such as ordinary mineral lubricating oil. It is claimed that such a layer is not only water-proof,

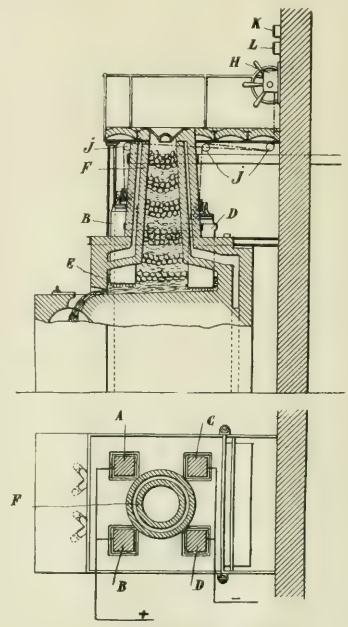


FIG. 2. REDUCTION FURNACE.

but is a comparatively good electric conductor. A transverse section of an apparatus with an electrode constructed according of this invention is shown in Fig. 3. The electrolytic vessel *a* contains the sheet metal conductor *b*, preferably made of lead, which receives current from the main conductors *e*. The carbon anode *c* may be made of bricks of molded coabon, or of bricks cut out of gas retort or any other suitable form

of carbon. The layer *f* composed of finely divided carbon combined with the non-oxidizable oil is rammed into the space between *b* and *c* care being taken that only just so much non oxidizable oil is used as will cement the particles of carbon together and fill the interstices between them sufficiently to prevent the passage of liquid through them. Heavy petroleum lubricating oil is stated to be suitable; *d* is a revolving cathode of lead or platinum. When applied to a flat electrode, the sheet metal conductor is covered on both sides, and at the edges with a layer made up as described above.

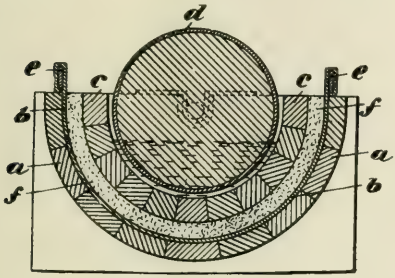


FIG. 3.—CARBON ELECTRODE.

Manufacture of Sulphuric Acid.—P. G. Salom, Philadelphia. Patent 755,247, March 22, 1904. Application filed June 17, 1902.

The principle of operation in this process is the oxidation of sulphurous acid gas in the presence of water by means of electrolytic action. The apparatus proposed for carrying out the process is shown in the adjoining Fig. 4. Dish-shaped receptacles A, A′, A², etc., to A⁸, are arranged in the form of a stack on the base B. Each vessel is supported on the top rim of the next one below it by means of a flange *a*, separated from the rim of the under vessel by a gasket *b* of rubber. Rubber tubes *c* lead from the top of one vessel into the bottom of the next one above, and are preferably arranged alternately at opposite sides. A tube *d* leads into the bottom of the lowest vessel A⁸, and is provided with a two-way cock D, in order to make connection either with the source of the sulphurous acid gas *r* with the receiving tank for the sulphuric acid produced. A tube E which leads from the top vessel can be connected either with an air pump or other source of pressure, or with a water supply. The positive pole of the current is connected to the lowest vessel, while the negative pole is attached to the uppermost vessel. The various vessels are filled with water to the levels indicated by *f* and sulphurous acid gas is admitted through pipe *d* and allowed to rise up through the water in all the vessels, while at the same time electrolysis is allowed to take place. The gas not absorbed in the solutions and the hydrogen evolved in the process pass out through the tube E. The oxygen set free by electrolysis is stated to combine with the sulphurous acid to form sulphuric acid in solution, and the operation is stated to be conducted until the maximum quantity of the product has been obtained in the lowest tank. The cock D is then turned and the supply of sulphurous acid thus shut off, while pressure is applied through pipe E and the solution forced out from each upper vessel into the next lower one, while the lowest discharges its contents into the receiving tank. When a quantity of solution equal to the contents of the lowest tank has been discharged, the connections are established as they were before, the uppermost tank filled with water, and the operation resumed as described above. No details as to voltage and current strength and density and results obtained are given in the specification.

Extraction of Copper from Comminuted Mineral Mixtures.—E. A. Le Sueur, Ottawa, Canada. Patent, 755,302, March 22, 1904. Application filed, May 27, 1899.

A process of extracting metallic copper from mixtures, containing but a very small percentage, usually less than 1 per cent of the metal. Certain cupric compounds, the hydroxide being preferred by the inventor, in solution in ammonia or its carbonate, will slowly oxidize metallic copper. The inventor claims to have discovered that such a solution has its oxidizing powers extraordinarily enhanced by the addition of certain apparently inert salts of ammonia, the sulphate and the nitrate being preferred for this purpose. The use of ammonium chloride is referred to as being objectionable on account of the danger of the formation of nitrogen chloride in case electrolytic precipitation be adopted. The composition of the solvent solution is given as $Cu(OH)_2 + X\ NH_4(OH) + (NH_4)_2SO_4 + ag$, in which formula X is greater than 2 and ammonium sulphate may be replaced by other salts of ammonium. When this solution is applied to the mixture containing copper, *e. g.*, the waste sands from the Calumet and Hecla Mining Co., the cupric hydroxide is stated to be reduced, sometimes completely, to the cuprous form, according to the equation $Cu + Cu(OH)^2 + X\ NH_4(OH) + (NH_4)_2SO_4 + ag = Cu_2(OH)_2 + X\ NH_4(OH) + (NH_4)_2SO_4 + ag$. The copper may be extracted from this solution either

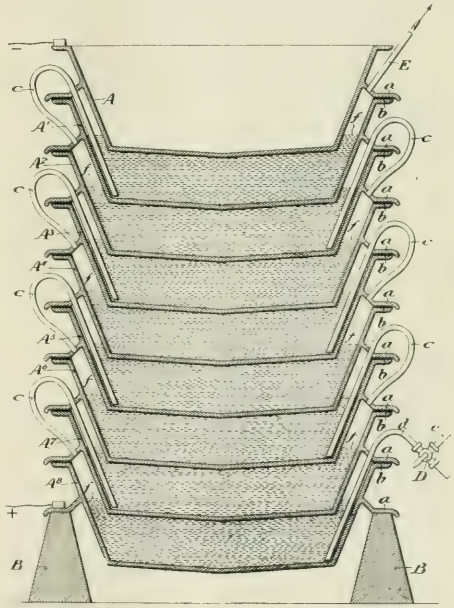


FIG. 4.—APPARATUS FOR MANUFACTURE OF SULPHURIC ACID.

by electrolysis or by chemical precipitation. The proposed method of working, where it is practicable to do so, is to dissolve the copper without (or with but little) access of air to the cuprous form, and to electrolyze this solution with an insoluble anode, with exclusion of the air. In this case the oxygen set free at the anode will oxidize half of the cuprous solution to the original cupric solution, and the copper from the other half will be deposited, the amount deposited per unit of current being twice that which would be obtained from a cupric solution. The re-oxidized cupric solution is then available for use again for leaching purposes. On account of the unavoidable waste of solution and atmospheric oxidation in

practice, the above statement is not strictly true, but it is claimed that these processes may be regulated so as to just neutralize each other and keep the amount of cupric copper at the end of any run constant. Platinum is proposed as material for the insoluble anodes. Iron and carbon anodes are also mentioned, the product of electrolysis at the anode in the first case being ferrous iron soluble in ammonia, which is afterwards oxidized by air to the ferric form and precipitated. The chemical method of extraction proposed by the inventor consists in adding to the solution a quantity of chamber sulphuric acid less than sufficient to neutralize the ammonia and filtering of the precipitated hydroxide of copper. The ammonia is left in excess in order to avoid an acid reaction and to retain a certain amount of copper in the solution in order to use the latter over again.

Storage Batteries.

Process of Preparing Electrodes for Storage Battery Cells.—O. Frank, Detroit. Patent 753,383, March 1, 1904. Application filed May 2, 1903.

The first step in this process consists in placing the lead grid-form plates into an electrolyte composed of a mixture of 95 per cent H_2O, 5 per cent of Na_2SO_4 and 0.7 per cent of $KClO_3$. Usually 11 plates are treated at one time, 5 being positive and 6 negative. The mixture is electrolyzed for about 50 hours at a temperature of about 20° C., with one ampere. It is claimed that by this treatment the positive plates are penetrated to the depth of 1 mm, with chlorine, which can be noticed by the white coat with which the plates are covered; it changes, however, shortly to a dark brown color. The plates are then thoroughly washed in distilled water, and put into a weak solution of H_2SO_4, in order to remove the chlorine; to make the removal of chlorine complete, he uses the positive as negative plates and substitutes sheets of lead for the positive plates. He then connects up as before and charges with a current of two amperes for about 50 hours. At the end of this time the peroxide is said to appear, the brownish color of the plates being replaced by a grayish spongy coating. The plates are then taken out, thoroughly washed in distilled water, and dried in air at a temperature of 300° C. This treatment is claimed to give the plate a solid coating of lead superoxide, the plate being then taken for a practical positive plate, and the active material introduced into it.

Storage Battery Tray.—Thomas A. Edison, Llewellyn Park, N. J., assignor to Edison Storage Battery Co. Patent 754,858, March 15, 1904. Application filed November 28, 1902.

The storage battery tray described in the specification consists of a box with solid bottom and ends, open top and substantially open sides, and adapted to hold four cells. Provisions are made for the purpose of minimizing the danger of short circuiting through moisture, and details are also given as to the construction adopted for holding the cells securely in place. The best results are stated to be secured when the tray is formed of cypress, as this wood appears to be less affected by alkaline solutions. The wood is preferably paraffined, the latter operation being performed by immersing the wood either in bulk or boards in a bath of molten paraffine, in the presence of a partial vacuum produced by a vacuum pump.

Reversible Galvanic Battery.—Thomas A. Edison, Llewellyn Park, N. J., assignor to Edison Storage Battery Co. Patent 754,859, March 15, 1904. Application filed November 28, 1902.

The battery receptacle is preferably made of thin sheet-steel carefully nickel plated and with corrugated sides, provided on its inside with a lining of hard rubber or other insulating material. The bottom of the receptacle is formed with a series of bosses, which extend through corresponding openings of a nickel-plated plate, which rests on the bottom. This plate is provided with ears which engage a series of glass rods, preferably formed with slots or grooves, which serve the purpose of receiving the bottom ends of the vertical electrode plates and properly spacing them and holding them in place. The vertical electrode plates carry sectional corrugated perforated nickel-plated spring steel pockets, which contain the active material. A series of glass tubes, which are arranged parallel to the plates within the spaces formed between adjacent pockets and rest on the bottom plate mentioned above, are used for the purpose of separating the plates mechanically and insulating them electrically. It is claimed that the use of glass insulators makes a very light and cheap construction, while at the same time the insulators are absolutely unaffected by electrolytic action in the alkaline solution.

Storage Battery.—M. C. Burt, Chicago. Patent 754,969, March 22, 1904. Application filed August 13, 1903.

The cell consists of two positive and three negative plates. In order to counteract the heat created in the cell the inventor arranges a pipe of any suitable "insulated" material, bent into a series of parallel coils, one series of parallel coils being interposed between each two of the plates and on the outside of the two end plates. Air under pressure is forced through these coils by means of a pump, fan, etc. The adjoining series of coils are connected over the upper edges of the plates, and the lowest end of the last series of coils is connected to a similar coil on the bottom of the plates. The latter coil is provided with apertures, through which the air can pass into the battery solution. The bottom coil is also designed to keep the plates a sufficient distance above the bottom of the cell in order to prevent short-circuiting caused by particles of active material falling on the bottom, while the coils between the plate are intended to serve as separators.

Storage Battery Construction.—S. Lake, Bridgeport, Conn. Patent, 755,142, March 22, 1904. Application filed December 17, 1903.

The invention relates to that class of storage batteries in which each cell contains two series of plates, the members of each of which are connected by a common bus bar, and the object of the invention is to form this connection in such a way that plates may readily be removed without disturbing the others. A mechanical construction for this purpose is described in detail and illustrated in the specification.

Galvanic Cells.

Battery Stopper.—Albert Mueller, New York. Patent 754,081, March 8, 1904. Application filed October 24, 1903.

The invention relates to a stopper for batteries on vehicles, which is intended to prevent the splashing of the electrolyte out of the battery vessels. It is constructed in such a way that it allows the gases to escape, while the liquid is introduced through a vertical passage, which communicates with a transverse passage leading into the interior of the vessel. The bottom part of the stopper is thus left unperforated and the liquid splashing up aginst it is prevented from escaping to the outside.

Miscellaneous.

Apparatus for Electrical Production of Nitrogen or Other Compounds.—J. von Kowalski and T. Moscicki, Freiburg, Switzerland. Patent 754,147, March 8, 1904. Application filed February 21, 1903.

The apparatus used by the inventors is shown in the adjoining Fig. 5; *b* is an alternator, and *a* the primary of a transformer, the secondary C supplying currents to the leads across which are arranged in parallel the "consumption branches," Each of the latter contains a pair of electrodes *e f* in a receptacle *k*, to which the air or other gases to be acted upon are supplied, in series with a condenser *g* and an inductance coil *h*. In order to eliminate or materially reduce the production of a wattless component in the secondary, a main

inductance coil *i* is connected across the leads in parallel with the consumption branches. Each group of parallel consumption branches is in series with a group inductance coil *l*, so proportioned that it will maintain the original frequency of the alternating currents in all that part of the secondary circuit outside of the consumption branch, by preventing the propagation of the oscillatory currents beyond its respective consumption branch. A series of electric arcs are formed between the electrodes *e* and *f* by the charging and discharging of the condensers *g*, the reciprocal action of the condensers on each other producing oscillatory currents of a high frequency in each consumption branch, modified by the inductance of the coils *h*, whereby a stream of sparks in the

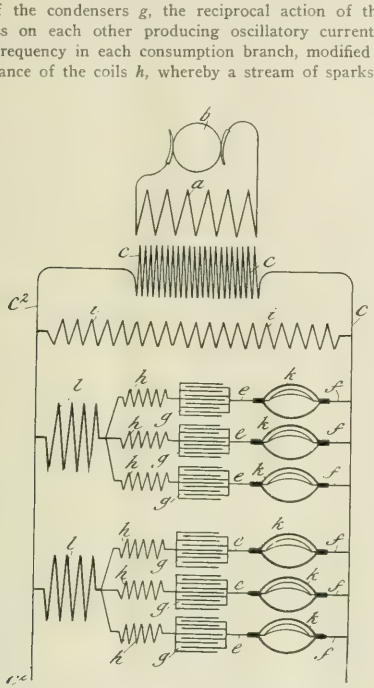


FIG. 5.—APPARATUS FOR PRODUCING NITRIC ACID ACID FROM AIR

nature of an arc is maintained in each receptacle *k*. These arcs, acting upon the air or gas in the receptacle produce the desired nitrogen compounds, circulation being maintained by any suitable means. The following interesting data, taken from a plant for the production of nitric acid, are given: The secondary circuit had an e. m. f. of 50,000 volts, producing spark-arcs of about 24 centimeters in each spark gap. In each consumption branch the current was 0.05 amperes, and the frequency was about 6000 alternations per second, while the frequency of the alternating current in the secondary circuit outside of the consumption branches was 50 alternations per second. The apparatus required 33 hp. of electric energy, and with this there was obtained 1155 grams of nitric acid per hour from the surrounding atmospheric air, or 35 grams of nitric acid per hp. hour. No attempt was made to obtain any of the other by-products, such as oxygen, nitrogen dioxide, nitrogen monoxide, etc. It was found that the frequency of the current in the consumption branch should have a minimum of 6000 alternations per second, and while the production of nitric acid was not essentially influenced up to 10,000 alternations per second, it was found advisable not to go beyond this latter frequency, because then the output of nitric acid began to fall.

Ozonizer.—A. Vosmaer, Nieuwersluis, Amsterdam, and A. Lebret, Utrecht, Netherlands. Patent 754,261, March 8, 1904. Application filed September 11, 1902.

The apparatus consists of a transformer, the secondary of which is connected with a condenser in shunt, while a choking coil is interposed in series in one of the branches between one terminal of the transformer secondary and one terminal of the condenser branch. The ozonizing apparatus, which works without any interposition of dielectrics between the electrodes, is also connected across the conductors from the secondary. The effect of the condenser is to increase the effective secondary voltage to a higher value, chiefly depending on the relation which exists between the current passing in the shunt of the condenser and that in the ozonizer. It is stated that the two phenomena resulting from the employment of the condenser (superelevation of the secondary tension and suppression of arcing) are intimately connected one with the other, and that the sparking produced in the ozonizer decreases in proportion to the degree of superelevation of the secondary voltage. Thus, the more the secondary voltage is superelevated, providing the intensity of the current in the branch of the ozonizer is low, the better will be the production of electric effluvia which require a high tension, but a small current.

Portable Electric Lamp.—H. C. Hubbell, Brooklyn, N. Y. Patent 753,138, February 23, 1904. Application filed July 2, 1903.

The inventor describes a portable lamp, with a box of thin sheet-steel, containing a number of cells, also of thin steel and lined on the sides with thin sheet copper or brass or other metal which can be amalgamated, and is not affected by the solution. A quantity of zinc amalgam is placed in the bottom of each cell in direct contact with it. The other electrode is formed by spongy or porous pure silver, which is suitably fastened to nickel wires or iron, nickel-plated wires, suspended from a disc. The cells are partly filled with caustic potash or caustic soda solution.

Means for Providing Zinc in Radiators.—W. R. Kinnear, New York, N. Y. Patent 752,844, February 23, 1904. Application filed September 8, 1903.

The object of the invention is to prevent corrosion in sheet-metal radiators for steam and hot-water heating, by introducing a metal like zinc, electronegative to the metal of the radiator. Various forms of suspending cubes or blocks of zinc in the radiators are shown in the specification.

SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.

Industrial Electrochemistry.

Ferronickel Direct from Pyrrhotite.—One of the interesting metallurgical problems, the solution of which was undertaken during the last years in Sault Ste. Marie, was the production of ferronickel direct from the Sudbury nickeliferous pyrrhotite. A most interesting account of the manner in which this problem "was handled, although as yet not finally disposed of," is given by E. A. Sjöstedt in the *Iron Age* of February 18. The developed deposits of the Sudbury pyrrhotite (iron monosulphide) contain from 2 to 3 per cent nickel and 1 to 2 per cent copper, besides a variable amount of gangue. From this ore it was proposed not only to extract the nickel and copper, but

the sulphur and iron as well. The first step taken consisted in sorting the ore in two grades, of which the one of low sulphur and high gangue and copper contents was to be treated in the usual manner of matte making, whereas the ore rich in sulphur, iron and nickel, but low in copper was to be assigned to the ferronickel industry. Since the copper is present in the form of veins of chalcopyrite (Cu_2S, Fe_2S_3), readily discerned by its deep yellows color, the separation of it, as well as that of the gangue, was accomplished on the sorting table at the rock house. In this manner they obtained a shipping ore, containing about 3 per cent nickel, 0.5 per cent copper, 28 per cent sulphur, 50 per cent iron and 0.01 per cent phosphorus—the raw material for the new industry. The modus operandi proposed for treating this ore was simply to eliminate first the sulphur by roasting, with the recovery of the evolved sulphur dioxide gases for the manufacture of a sulphite liquor for the then contemplated sulphite pulp mill, and second, to convert the desulphurized (now an oxide of iron and nickel) ore into a ferronickel pig either by electric smelting or by the usual blast furnace process.

It was first attempted to treat the ore, finely crushed in a Herreshoff pyrite roaster; but this kiln (which was designed for roasting pyrites, *i. e.*, bisulphide of iron, instead of pyrrhotite, *i. e.*, monosulphide of iron) did not fill the requirements, the low sulphur contents of the ore being insufficient to keep up a continuous roasting heat under the circumstances. Sjöstedt designed, therefore, a new roasting furnace and took special care to eliminate the loss of heat by radiation, to apply the roasting heat generated to the best advantage, to exclude any excesses of air over and above that required for the oxidation of sulphur, and to supply an auxiliary source of heat in case of need. The new Sjöstedt roaster (which was found entirely successful in the solution of the problem of getting a sufficiently strong gas from pyrrhotite, suitable for the manufacture of sulphuric acid and sulphate liquor, as well as for liquid sulphurous anhydride) embodies the following special features: The combination of four single furnaces in one battery, disposed equidistant from a common center; a minimum distance from the bottom of the floor to the top of roof arch of each heating chamber made possible by the construction of the arm and the manner in which it is secured to the center shaft, it being pushed home into position simply by a straight (not lifting) motion and a quarter turn twist; a round rabble arm, cast hollow, but having both ends closed so as to prevent any inflow of air from the center shaft to the roasting chamber, the air for combustion being admitted through special pipes, provided with valves for control; a secure locking device of the arm to the shaft; separate muffle chambers for applying auxiliary heat, having no connection with the roasting chambers; a screw device for feeding the ore from the hopper to the roaster.

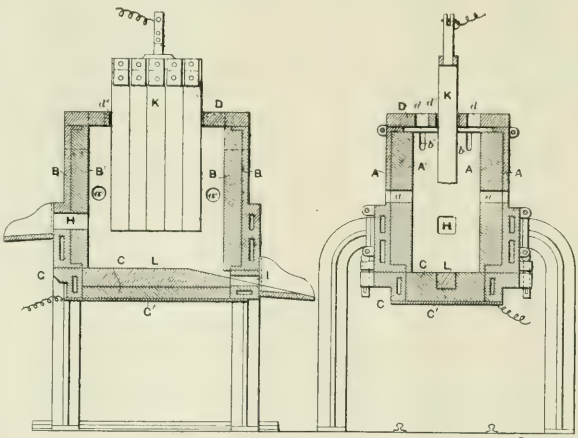


FIG. 1.—FERRONICKEL FURNACE.

Four of these batteries of kilns, *i. e.*, in the whole 16 units, were used with a total capacity for treating 40 tons of ore per day. At first water-gas was used for providing a required auxiliary heat, but by gradually improving the details of the roasters, they finally succeeded in roasting pyrrhotite without any extraneous fuel, even when averaging below 20 or 25 per cent sulphur, producing a roaster gas with 7 to 9 per cent sulphur dioxide, and a ferronickel cinder with 1 to 3 per cent of sulphur. At times they succeeded in reducing the sulphur contents of the ore to 0.75 per cent, but in doing so the roaster gas naturally became weak and unfit for the sulphite mill, whereas, when making a rich gas for the mill the sulphur contents invariably increase. The author therefore suggests to divide the roasting operation in two separate stages, the object of the first being an increased product, a strange gas and only an incomplete roasting, leaving the ore with a sulphur content of about 4 to 5 per cent, and the second operation aiming at a final dead roasting of the still hot fines in an auxiliary furnace and by means of a highly oxidizing heat.

The first intention was to subject the roasted fines to electric smelting, and for this purpose an electric furnace was constructed, as shown in Fig. 1, and containing a rectangular water-jacketed body case, A B, with refractory lining, A^0 B^0, provided with a slag notch, H, vent holes, a^0, and stoke holes, b^0, a water-jacketed bottom frame, C, held removably on that body, and provided with a refractory lining on a plate, C^1, screwed to that frame, and having a tapping-hole, I, provided in one of the ends; a cover of refractory material D, having feed and vent holes, d and d^1, and opening for the electrode; an upper electrode, K, and a bottom electrode, L, embedded in the bottom linging, C^0, and its ends in contact with the metallic frame of the bottom.

In this furnace a ferronickel pig was made from a poor roasted pyrrhotite, with about 3 per cent sulphur, and 53 per cent iron, at the rate of 60 pounds per hour, "with an electric energy* of 108 kw. (135 amperes, 80 volts = 144 hp.)." The same power produces, therefore, per year, 225 gross tons, corresponding to an expenditure of energy equal to 144 hp. year. Hence, the production of one gross ton requires the expenditure of 0.64 hp. for one year, or of 230 hp. for one day, or of 5000 hp. for one hour. With a furnace of 300 to 500 hp., which he considers would be more economical, he thinks that 180 to 200 hp. would probably suffice for obtaining a gross ton of metal per day. But even at that rate the intended plant for the manufacture of 50 tons of ferronickel pig per day would require an electric installation of 10,000 hp., which meant more time and expenditure than was considered necessary; consequently, it was decided to dead roast the ore, briquette the roasted fines and convert the briquettes, together with a proper addition of non-nickelferous iron ores, by the ordinary blast furnace process into a pig of desired nickel contents, subsequently treating the same by the Bessemer or open hearth methods for the manufacture of a ferronickel steel.

Recent Advances in Electrochemistry.—A series of three Cantor lectures on this subject is being delivered by B. Blount, the first lecture being given in abstract in London

* There is some mistake in these figures, since the electric power, corresponding to 135 amperes and 80 volts is 10.8 kw., not 108 kw.

Electrician March 11. In commencing, the lecturer stated that the electrochemical industries, at the present time, appeared to be passing through a transition stage. Competition between chemical and electrochemical methods of manufacture is considered by him as extremely beneficial, since it tends to stimulate workers in both fields to further exertions. As a result, he finds that any electrochemical process which has to compete with purely chemical methods, is in a more flourishing condition than those which have no competition to fight with. As an example of the latter class he cites pure carbonates which can only be produced electrolytically, and therefore this particular branch of the industry is not in quite so healthy a condition as it might be. The electrolytic "winning" of copper is much more difficult than its refining, which latter now depends to a large extent on engineering and not so much on the operator's scientific knowledge of electrochemistry. He thinks the multiple system of cells to be better than the series system, although much depends on convenience. Americans have taken the lead in the electrolytic copper refining industry, owing to the fact that they have successfully endeavored to reduce the labor and handling expenses. Dealing next with zinc, the lecturer said that there is no demand for the pure metal, and in any case it can be produced in a pure state by distillation, which method, however, is expensive. It can be prepared electrolytically from an aqueous solution, but when the latter is slightly acid, then an inconveniently high e. m. f. is required; on the other hand, when it is neutral or slightly alkaline, the zinc is obtained in a spongy form. He thinks that one may hope for success in obtaining zinc from a fused salt. Concerning nickel he said that "there are difficulties in separating it from its alloys, and pure nickel produced electrically is hardly known now, owing to chemical competition. It would pay to make a copper-nickel alloy and deposit copper only, recovering the nickel chemically." The lecturer expressed considerable scepticism as to electrolytic processes for the production of lead, and said that electrical methods, no matter how ingenious, cannot compete with existing methods.

Electric Smelting of Complex Sulphides.—In the *Engineering and Mining Journal* of March 24th, A. A. Beadle discusses the problems involved in the treatment of the ores of the Broken-Hill saddle reef in New South Wales, which consist of an extremely finely interlaced mass of crystals of argentiferous galena and ferruginous zinc blende with a gangue of garnet, rhodonite and feldspar, together with traces of arsenic, copper and gold. The average composition of the ore is lead 18 per cent, zinc 20 to 25 per cent, iron 6 per cent, sulphur 20 per cent, gangue 25 per cent, silver 10 to 15 ounces, and gold 2 to 3 dwt. per ton, leaving about 10 per cent for moisture. At present about five tons of ore, having a total metallic value of about $150, are concentrated in order to obtain one ton of concentrates, assaying 60 per cent lead and 31 ounces silver. Magnetic concentration has lately enabled a zinc blende assaying 45 per cent zinc, to be produced. In view of the structure of the ores, the complete separation of the metals makes it necessary to chemically disintegrate or dissolve the complex minerals. This has been tried either by means of an electrolysis of aqueous solutions, or by electrolysis of fused salts. In the electrolysis of aqueous solutions it is necessary to bring the minerals into solution either separately or, if dissolved together, they must be separately deposited in a pure and coherent condition. None of these essentials, as a matter of fact, have ever been fully realized in any of the numerous processes devised for this purpose, and which are briefly sketched by the author. Nevertheless, the large margin of profit in working one of these complex ores warrants a continuation of investigations in this direction. If we have an ore assaying lead 20 per cent, zinc 20 per cent, and silver 10 ounces, the total metallic value is about $37 per ton. Now, if the cost of mining is $3 per ton, the carriage by mail to the Australian seaboard $3.50, the cost of transport by sea to Europe $6.25, and the cost of bagging, loading and unloading $2.50, the margin of profit in Europe would be $22; whereas, at the Australian seaboard, while allowing for carriage of the metals to Europe, it would be $28 per ton of ore. This, however, does not allow for miners' rights and profits. In order that the metals—lead, zinc and silver—may be reduced electrolytically in the fused state, they must be first converted into their haloid salts. Once this is successfully accomplished they can be dealt with almost as desired, for the fused chlorides are readily amenable to fractional electrolysis, and the impurities being removed at a preliminary step, the metals may be reduced in pure marketable condition, and even the noble metals removed as a rich lead alloy before the bulk of the lead is reduced. The current efficiency is high, the voltage low, and the size and cost of plant for a given output are considerably lower than in wet processes. The conversion, therefore, either directly or indirectly, of the complex sulphides into the fused chloride constitutes the main part of this problem. The author refers to the Swinburne-Ashcroft (which was described at length in Electrochemical Industry, August, 1903, page 412). He thinks that the results so far obtained are such that great hope of the ultimate success of this departure is reasonably held out. He finally points out that in order to smelt a complex ore by a substitution method the whole of the zinc in the ore and that used in replacing the lead and silver must be entirely recoverable without loss, a state of affairs realized by electrolytic methods alone.

Treatment of Copper Ores by Means of Ferric Sulphate.—In *Metallurgie* January 15, February 8 and 22, F. Thomas gives the results of a series of laboratory experiments, in which he investigated the problem of leaching copper ores by means of ferric sulphate. The ore with which he experimented had the following composition: 44.7 per cent SiO_2 + gangue; 13.5 per cent Cu_2S (corresponding to 10.5 per cent of copper), 25.25 per cent Fe_2S_3, 5.76 per cent Fe_2O_3, 0.18 per cent MnO, 7.5 per cent Al_2O_3, 0.34 per cent P_2O_5, and 2.82 per cent CaO, with small traces of Sb, Sr, Mg and K. The main results of his experiments are as follows: The double sulphides of copper, which occur in nature, require for their complete transformation by means of ferric sulphate such a long treatment and so fine crushing, that a commercial application of this method of leaching does not pay under the conditions existing in most countries. Copper-iron sulphides, artificially prepared, also resist the action of ferric sulphate in the same way as the natural ones. Free copper sulphides and oxides react with ferric sulphate in aqueous solution easily and quickly. The reason to which the delay of the action of the ferric sulphate in the former cases is due must, therefore, lie in the chemical affinity between the ingredients of the natural and artificial sulphur ores in the copper ore. The presence of a larger quantity of ferrous sulphate in the solution impairs the solution of copper from cuprous sulphide by means of ferric sulphate. The method suggested in the Siemens & Halske process for roasting copper ore, so that the main quantity of the iron is transformed into oxide while the main quantity of the copper remains as cuprous sulphide, is practically impossible. Neither can satisfactory results be obtained by means of dead-roasting of sulphide ores, for the reason that at the temperatures required for this purpose basic silicates are formed by means of a combination of the copper oxide with the silicates of the gangue, and that perhaps also salts of the type Fe_3O_4 are formed by combination of the oxides of copper and iron; such salts are acted upon very slowly by ferric sulphate. The double sulphides must therefore be destroyed by means of a method of oxidizing roasting at so low a temperature that the formation of the compounds just mentioned is impossible. This temperature is about 450 to 480 degrees. The product thus obtained contains the copper essentially in the form of sulphate. The low temperature of roasting permits the use of simple furnaces, and a crushing of the ore is sufficient, corresponding to 484 meshes per square centimeter. The

leaching can be so conducted that a solution consisting essentially of copper sulphate is obtained with only small quantities of iron.

Nickel Refining.—In the issue of *Metallurgie* of March 8 E. Guenther describes laboratory expriments which he has made on the direct electrolytic treatment of concentrated nickel matte, obtained from New Caledonian ores, and having the following composition: Ni and Co 75.90 per cent, S 23.89 per cent, Fe 0.41 per cent, Cu 0.16 per cent, SiO_2 0.10 per cent. His main test was made with a vessel of 3 liters contents, and the run covered forty days (except at night and on holidays). Two anode plates of 15 mm. thickness and of 847 and 725 grams weight were placd at both sides of a cathode of sheet nickel. The active surfaces were about 200 sq. cm., if the surfaces, opposite to each other, are counted. He used generally a current density of 250 amperes per square meter, the voltage at the terminals of the bath being about three. Exceptionally higher current densities up to 350 amperes per square meter, and lower ones down to 100 amperes were used; in the latter case the voltage decreased to 1.5 volt, or below. He could not find any considerable influence of the current density, but recommends for several reasons which are not stated, 250 to 275 amperes per square meter. The ampere hour efficiency was in the beginning 92 per cent and decreased later gradually down to 80 per cent, for reasons not exactly determined; he believes that the decreasing size of the anode plates has to do with this phenomenon. "The electrolysis is conducted advantageously at a higher temperature," but no exact data are given. Nickel sulphate was used as electrolyte, but from his experience the author concludes that nickel chlorides may also be used. During electrolysis the anode plates are dissolved, especially at the edges, and on the sides, opposite to the cathode, the solution being apparently absolutely uniform. After a longer time the reverse sides of the anodes also showed signs of solution. The electrolyte was repeatedly analyzed, and it was found that nickel, copper and iron go simultaneously into solution according to the composition of the anode plates. The surface of the anodes remains plane, but is covered after some time with a coherent soft mass, which, however, did not increase the internal resistance of the cell. When at times the voltage at the terminals of the cell increased, it could not be shown that this was due to the anode slime; moreover, this increase in voltage was only temporary, and never more than 0.5 to 0.6 volt. At the end of the test the anodes were reduced to plates of an average thickness of 1 mm., and of an active surface, half the original one. The anodes still were coherent plates, the weight being 22 per cent of the original weight. The cathodic nickel deposit was, throughout, satisfactory; during the forty days' test he deposited more than 1 kg. nickel on the cathode, the plate having finally a thickness of 8 mm. in the central part, and 14 mm at the edges. The structure of the cathodic nickel was dense, its composition, 99.715 per cent Ni, 0.20 per cent Cu, 0.085 per cent Fe, so that the copper dissolved from the anode was not fully deposited on the cathode, while the amount of iron was considerably reduced. The anode plates at the end of the test consisted of about 80 per cent sulphur and 20 per cent undissolved sulphides; the latter contained 51.4 per cent Ni, 1.05 per cent Fe and 12.1 per cent Cu. The electrolyte is to be kept slightly acid; the contents of fre acid—either sulphuric or hydrochloric acid, etc.—should be 0.03 to 0.25 per cent. At the cathode more nickel is deposited than is dissolved from the anode; the balance is to be continually supplied to the bath in form of a concentrated salt solution.

Production of Tin from the Ores.—In *Metallurgie*, January 15 and February 8, E. Bahlsen gives a review of the present conditions of the metallurgy of tin. The production in 1902 in the world was about 88,279 tons, the principal place of mining being the Malay Peninsula. The principal mines are not inexhaustible, and it is probable that in about ten years the production of tin from ores will rather decrease than increase, if new mines are not found. On the other hand, most of the tin which is now used for the tinned iron cans for preserves is afterwards won back by electrolytically de-tinning the scraps. At present about 35,000 tons of tin scraps are treated per year electrolytically in Germany, from which 2 to 2.5 per cent, *i. e.*, about 800 tons of tin, are won, amounting to about $500,000. There is no danger of an overproduction of tin for the next few years, and it is probable that the price will remain high.

Alkali Metals by Electrolysis of Fused Salts.—In *Metallurgie January* 15, L. Stockem gives some supplementary notes on his work on the production of alkali and alkaline earth metals by electrolysis of their fused salts (see Electrochemical Industry, November, 1902, p. 104). He discusses first the behavior of sodium in fused sodium chloride. The solution of sodium in chloride may either be a simple solution process, or may be due to the formation of a subchloride, like Na_2Cl, as Rose believes; the present author shows that the latter assumption is very improbable. Concerning the production of calcium by electrolysis of calcium chloride, he points out that to get a good efficiency, it is absolutely necessary to keep the temperature of the cathode so low that the formation temperature of Ca_2Cl_2 is not attained; for this purpose it is necessary that the calcium deposited upon the cathode is constantly cooled to a temperature near its melting point, although the average temperature of the fused salt may be higher. The melting point of strontium was found to be between 570° and 660° C.

Electrolytic Production of Threevalent Vanadium Salts.—In the *Zeit. f. Elektrochemie*, February 26, A. Buelteman describes experiments in which threevalent vanadium salts were produced by electrolytic reduction from fourvalent salts. The production of $V_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$ by this method is first described. He employed a diaphragm cell, and used as anodic liquor sulphuric acid of the same concentration as is contained in the cathodic liquor. For the latter 100 cc. of a sulphate solution of the fourvalent vandium was used. The voltage of electrolysis was 8 to 9 and the temperature of the electrolyte at the end of the electrolysis was 80° C. If the catholyte is then cooled in a closed vessel, $V_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$ crystalizes out in form of large crystals of a blue-violet color. This salt can exist with the same chemical compositions in two different modifications. For making $V(C_2O_4)_2.(NH_4)_2.3H_2O$ and $V(C_2O_4)_2.K_2.3H_2O$ he prepared the catholyte by dissolving V_2O_5 by means of oxalic acid as a fourvalent salt. This liquid was electrolytically reduced until the vanadium was all in the threevalent form. Ammonium or potassium oxalate was then added and heated, and the above-named substances were then crystallized out. It is possible to use comparatively high-current densities and the ampere hour efficiency is nearly 100 per cent.

Theoretical and Experimental Electrochemistry.

The Structure of the Atom.—The electron theory has become of the greatest importance for chemistry, not only on account of its intimate relation to the ionic theory in elctrolysis, but also for the reason that it threatens to break down, or, at least to modify completely our former ideas on the nature of atoms. The atom is no longer considered the smallest particle which can exist, and is now, in fact, looked upon as a complicated system of numerous electrons. J. J. Thomson, who has already done very much for the development of the electronic, or, as he calls it, corpuscular theory, has now undertaken to study mathematically the consequences of this hypothesis, and to compare them with the facts, especially those represented by the periodic system of the elements. His extremely interesting paper is published in the March issue of the *Philosophical Magazine*. The first part of the paper is devoted to the discussion of a mathematical problem, suggested by the view that the atoms of the elments consist of a number of negatively electrified corpuscles enclosed in a sphere of uniform positive electrification. This mathe-

matical problem is the motion of a ring of n negatively electrified particles placed inside a uniformly electrified sphere.

Thomson shows that when we have a large number of corpuscles moving about in a sphere of uniform positive electrification, and when they are constrained to move in one plane, they will arrange themselves in a series of concentric rings. This arrangement is necessitated by the fact that a large number of corpuscles cannot be in stable quilibrium when arranged as a single ring, while this ring can be made stable by placing inside it an appropriate number of corpuscles. When the corpuscles are not constrained to one plane, but can move about in all directions, they will arrange themselves in a series of concentric shells. Now, Thomson shows that the properties which an atom would have on account of this ring or shell structure are analogous in many respects to those properties really possessed by the atoms of the chemical elements, and that in particular the properties of the atom will depend upon its atomic weight in a way very analogous to that expressed by the periodic law.

When there are N corpuscles, each carrying a charge e of negative electricity, placed in a sphere of positive electrification, then Thomson determines the distribution of the corpuscles when they are arranged in what may be considered the simplest way, *i. e.*, when the number of rings (or shells) is a minimum, so that in each ring there are as nearly as possible as many corpuscles as it is possible for the corpuscles inside to hold in equilibrium. The following table shows clearly the way in which various numbers of corpuscles group themselves; the numbers range downwards from 60 at intervals of 5. The uppermost row of figures gives the total number of corpuscles, while the lower rows give in each case the number of corpuscles as they arrange themselves in successive rings:

Table I.

60	55	50	45	40	35	30	25	20	15	10	5
20	19	18	17	16	16	15	13	12	10	8	5
16	16	15	14	13	12	10	9	7	5	2	
13	12	11	10	8	6	5	3	1			
8	7	5	4	3	1						
3	1	1									

We give also the entire series of arrangements of corpuscles for which the outer ring consists of twenty corpuscles. The uppermost row of figures indicates again the total number of corpuscles, while the lower rows give in each case the number of corpuscles in successive rings:

Table II.

59	60	61	62	63	64	65	66	67
20	20	20	20	20	20	20	20	20
16	16	16	17	17	17	17	17	17
13	13	13	13	13	13	14	14	15
8	8	9	9	10	10	10	10	10
2	3	3	3	3	4	4	5	5

Fifty-nine is the smallest number of corpuscles which can have an outer ring of 20, while, when the number of corpuscles is greater than 67, the outer ring will contain more than 20 corpuscles. The mass of an atom is the sum of the masses of the corpuscles it contains, so that the atomic weight of an element is measured by (*i. e.*, is proportional to) the number of corpuscles in its atoms. An inspection of table I. will now show that the various arrangements of the corpuscles can be classified in families, the grouping of the corpuscles in the various members of the family having certain features in common. Thus, for example, the group of 60 corpuscles consists of the same rings of corpuscles as the group of 40, with an additional ring of 20 corpuscles round it, while the group of 40 consists of the same series of rings as the group of 24, with an additional ring outside, while 24 is the group 11, with an additional ring, etc.

In general, we can divide the various groups of atoms into series, such that each member of the series is derived from the preceding member (*i. e.*, the member next below it in atomic weight in the same series) by adding to it another ring of corpuscles. We should expect the atoms formed by a series of corpuscles of this kind to have many points of resemblance. Take, for example, the vibrations of the corpuscles; they may be divided into two sets. First, those arising from the rotation of the corpuscles around their orbits: if all the corpuscles in one atom have the same angular velocity, the frequency of the vibrations, produced by the rotation of the rings of corpuscles is proportional to the number of corpuscles in the ring; and thus, in the spectrum of each element in the series there would be a series of frequencies bearing the same ratio to each other, the ratio of the frequencies being the ratios of the numbers in the various rings. The second system of vibrations are those arising from the displacement of the ring from its circular figure. If, now, the distance of a corpuscle in the outer ring from a corpuscle in the collection of rings inside it, is great, compared with the distance of the second corpuscle from its nearest neighbor on its own ring, the effect of the outer ring of corpuscles on the inner set of rings will only "disturb" the vibrations of the latter without fundamentally altering the character of their vibrations. Thus, for these vibrations, as well as for those due to the rotations, the sequence of frequencies would present much the same features for the various elements in the series; there would be in the spectrum corresponding groups of associated lines. Thomson regards a series of atoms formed in this way, *i. e.*, when the atom of the p' th member is formed from that of the $(p-1)$th by the addition of a single ring of corpuscles, as belonging to elements in the same group in the arrangement of the elements according to the periodic law, *i. e.* they form a series which, if arranged according to Mendeléef's table, would all be in the same vertical column.

The gradual change in the properties of the elements which takes place as one travels along one of the horizontal rows in Mendeléef's arrangement of the elements is also illustrated by the properties possessed by these groups of corpuscles. Thus we may consider the series of arrangements of the corpuscles in table II., given above, in all of which the outer ring contains 20 corpuscles. In the case of a total number of 59 corpuscles, the number of corpuscles inside is only just sufficient to make the outer ring stable; this ring will, therefore, be on the verge of instability, and when the corpuscles in this ring are displaced, the forces of restitution urging them back will be small. Thus, when this ring is subjected to disturbances from an external source, one or more corpuscles may easily be detached from it; such an atom therefore will easily lose a negatively electrified corpuscle, and thus acquire a charge of positive electricity; such an atom would behave like the atom of a strongly electropositive element. When we pass from 59 to 60 corpuscles, the outer ring is more stable, because there is an additional corpuscle inside it; the corresponding atom will thus not be so electropositive as that containing only 59 corpuscles. The addition of each successive corpuscle will make it more difficult to detach corpuscles from the outer ring, and will therefore make the atom less electropositive. When the stability of the outer ring gets very great, it may be possible for one or more corpuscles to be on the surface of the atom without breaking up the ring; in this case the atom would receive a charge of negative electricity, and would behave like the atom of an electronegative element. The increase in the stability of the ring, and consequently in the electronegative character of the atom, would go on increasing until it is a maximum for 67 corpuscles. A great change in the properties of the atom would occur with 68 corpuscles, for now the number of corpuscles in the outer ring increases to 21; these 21 corpuscles are, however, only just stable, so that the corresponding atom is strongly electropositive.

The arrangement of corpuscles in the group of 59, although very near the verge of instability, and therefore very liable to

lose a corpuscles, and thereby acquire a positive charge, would not be able to retain this charge. For when it has lost a corpuscle, the 58 corpuscles left would arrange themselves in the grouping corresponding to 58 corpuscles, which is the last to have an outer ring of 79 corpuscles; this ring is therefore exceedingly stable, so that no further corpuscles would escape from it, while the positive charge on the system, due to the escape of the 59th corpuscle would attract the surrounding corpuscles. Thus this arrangement could not remain permanently charged; for, as soon as one corpuscle had escaped, it would be replaced by another. An atom constituted in this way would be neither electropositive nor electronegative, but one incapable of receiving permanently a charge of electricity.

The group containing 60 corpuscles would be the most electropositive of the series; but this could only lose one corpuscle, *i. e.*, acquire a charge of one unit of positive electricity; for if it lost two, we should have 58 corpuscles—as, when the group of 59 had lost one corpuscle—and in this case the system would be even more likely than the other to attract external corpuscles, for it would have a charge of two units of positive electricity instead of one. Thus, the system containing 60 corpuscles would get charged with one, but only one, unit of positive electricity: It would therefore act like the atom of a monovalent electropositive element. The group containing 61 corpuscles would not part with its corpuscles so readily as the group of 60, but on the other hand, it could afford to lose two, and the system would act like the atom of a divalent electropositive element; similarly a group of 62 like the atom of a trivalent electropositive element.

The group of 67—at the other end of the series—has a very stable outer ring, but if the system acquired another corpuscle, the 68 corpuscles would arrange themselves with a ring of 21 corpuscles on the outside; which, however, would be nearly unstable. Therefore, the group of 67 corpuscles, as soon as it acquires a negative charge, would lose it again, and the system, like the group of 59, would be incapable of being permanently charged with electricity—it would act like the atom of an element of no valency. The group of 66 would be the most electronegative of the series, but this would only be able to retain a charge of one unit of negative electricity, and would therefore act like the atom of a monovalent electronegative element; similarly the groups of 65 and 64, like the atom of a bivalent, and trivalent electronegative element, respectively.

Now, this sequence of the properties which we should expect from the shell structure of an atom, is very like that observed in reality. Thus, we have the series of the elements:

He Li Be B C N O F Ne
Ne Na Mg Al Si P S Cl Arg

The first and last element in each of these series has no valency, the second is a monovalent electropositive element, the last but one is a monovalent electronegative element, the third is a divalent electronegative element, and so on. When atoms like the elctronegative ones, in which the corpuscles are very stable, are mixed with atoms like the electropositive ones, in which the corpuscles are not nearly so firmly held, the forces to which the corpuscles are subject by the action of the atoms upon each other may result in the detachment of corpuscles from the electropositive atoms, and their transference to the electronegative. The electronegative atoms will thus get a charge of negative electricity, the electropositive atoms one of positive, the oppositely charged atoms will attract each other, and a chemical compound of the electropositive and electronegative atoms will be formed.

To form an idea of the constitution of the atom of a radioactive element, Thomson refers to a result, obtained by him in his analysis of the stability of systems of corpuscles; such systems may be stable when the corpuscles are rotating with an angular velocity greater than a certain value, but may become unstable when the velocity falls below this value. Thomson considers the properties of an atom containing a system of corpuscles of this kind. He supposes the corpuscles to move originally with velocities far exceeding the critical velocity. In consequence of the radiation from the moving corpuscles, their velocities will slowly—very slowly—diminish. When, after a long interval the velocity reaches the critical velocity, there will be what is equivalent to an explosion of the corpuscles, the corpuscles will move far away from their original positions, their potential energy will decrease, while their kinetic energy will increase. The kinetic energy gained in this way might be sufficient to carry the system out of the atom, and we should have, as in the case of radium, a part of the atom shot off. In consequence of the very slow dissipation of energy by radiation the life of the atom would be very long.

Dielectric Constants.—In a paper, published in the February issue of the *Journal of Physical Chemistry*, H. Schlundt gives the results of a continuation of his former work on the dielectric constants of some inorganic solvents, and on the validity of the Nernst-Thomson rule, according to which a close parallelism exists between the dissociating power of solvents and their dielectric constants. A number of exceptions to the rule had been pointed out by him formerly, and a number of new examples had been found which followed the rule. The inorganic solvents studied followed the rule in a general way, although the parallelism between the ionizing power and the dielectric constant was far from close in several instances. The author has now determined the dielectric constants of some halogen compounds of phosphorus, arsenic and antimony, and also those of phosphorus, silicon tetrachloride and nitrogen tetroxide. The dielectric constants of the compounds in the solid state was found to be less than the value for the liquid; this drop in the value occurs upon solidification and depends to a great extent on the structure of the solid. Phosphorus trichloride, phosphorus tribromide and silicon tetrachloride have no ionizing power, and a low dielectric constant, and hence follow the Nernst-Thomson rule. There is also a parallelism between ionizing power and dielectric constant in antimony trichloride, arsenic trichloride and phosphorus trichloride; the same is the case for arsenic tribromide and nitrogen tetroxide.

Molecular Depression of Freezing Point in Concentrated Solutions.—The March issue of the *Physical Review* contains a very full account, by H. C. Jones and F. H. Getman, of an extended study of the molecular lowering of the freezing point of water produced by concentrated solutions of electrolytes. Of special interest are the conclusions drawn by the authors on the constitution of concentrated solutions. With but few exceptions electrolytes in general give abnormal molecular depressions of the freezing point in concentrated solutions. Among these exceptions are sodium, potassium and ammonium nitrates, and potassium dihydrogen phosphate. Among the chlorides those of the second group in the periodic system give greater molecular depressions than those of the first group. The curve for hydrochloric acid lies considerably above the corresponding curves for lithium, ammonium, sodium and potassium chlorides. In general, the freezing-point curve for any acid lies above those of the salts which it forms with the metals of the first group, while it lies below the curves for its second group salts. Further, the molecular depressions for similar substances are arranged in the order of their molecular weights. The conductivity curves for all the substances studied are perfectly normal throughout, showing absolutely no peculiarities in the region of dilution where the minimum of molecular depression manifests itself. The boiling curves, as far as studied, show a minimum at a greater concentration than the freezing-point curves. The main conclusion drawn by the authors is the existence of hydrates in concentrated solutions. In such solutions there is combination between the molecules of the dissolved substance and the molecules of the solvent, thus removing a part of the

solvent, as far as freezing-point lowering is concerned. To explain the conductivity result, it is also necessary to assume that there is a certain amount of electrolytic dissociation, together with the hydration existing in these solutions.

Electrolytic Analysis of Gold.—A Faraday Society paper by F. M. Perkin and W. C. Prebble on this subject is published in the *Electro-Chem. and Met.*, February. While they agree that the use of a double cyanide solution gives good deposits, yet the time necessary for the complete deposition in cold solutions is inordinately long. They are unable to agree with Classen that complete precipitation of the metal in hot solutions can be carried out in from 80 to 90 minutes. The sulphide method of E. Smith gives very brilliant deposits and in cold solutions the metal can be usually deposited in from 5 to 6 hours. The authors have found gold can be deposited in a very satisfactory manner from solutions of gold salts in ammonium thiocyanate. With current densities of 0.2 ampere per square decimeter the deposition of 0.05 to 0.08 gram in cold solutions is complete in from 5 to 6 hours. With a current density of 0.4 to 0.5 ampere per square decimeter it is generally possible, even at normal temperatures, to deposit the gold in from 1½ to 2 hours. The appearance of the deposit is generally better when obtained at a low current density and from solutions containing small quantities of gold. The authors have also carried out experiments to ascertain the best method for removing the deposited gold from the platinum cathodes. An extremely satisfactory solution is one containing potassium cyanide, with an oxidizing agent such as hydrogen peroxide, sodium peroxide or an alkali persulphate. With such a solution the deposit is removed in 2 to 3 minutes. They have also employed chlorine and bromine water successfully, but with these reagents the time required to remove the deposit is from 1 to 2 hours.

Storage Batteries.

Jungner Alkali Accumulator.—In the *Centralblatt f. Accum.*, March 1, an account is given of the Jungner accumulator exhibits at the recent Paris automibile exposition. It will be remembered that in its general mechanical construction it is similar to the Edison Accumulator. A method of Jungner for making positive nickel electrodes of the Planté type is also noticed, although it is at present more of scientific, than industrial value. Such nickel plates have a dark-brown color and look somewhat similar to peroxidized lead sheets. If the nickel peroxide is removed from the surface (by etching with dilute hydrochloric acid) a complicated structure of pure nickel appears, which is not unsimilar to moss. At present these plates have too low a capacity per unit of weight. They are formed in an electrolyte of a very dilute alkaline solution of sodium chloride, while for the second formation a 30 per cent solution of potassium hydroxide. The watt hour efficiency of the Jungner accumulator is not over 65 per cent, its ampere hour efficiency about 70 to 75 per cent. In a note in *Electro-Chem. and Met.*, February, the thickness of the nickel-plated steel from which the envelope for the active material is made is given as 0.2 mm., while the watt hours per kilogram of total weight of the Jungner cell "work out to an average of 23 to 24." M. U. Schoop thinks that a gelatinous alkaline electrolyte in the Jungner cell may be of use for ignition cells, but hardly for traction.

Lead Accumulator.—In the *Centralblatt f. Accum.*, February 1 and 15, F. Peters continues his very long serial on the electrolytic formation of lead peroxide from metallic lead. A summary of his results will be given after the completion of the serial. The *Centralblatt f. Accum.*, February 15, gives a brief description, by H. L. Joly, of the traction cell exhibited at the recent Paris automobile exposition. The *Elek. Neu. Anz.* of February 15 contains a note on the Lacroix accumulator, which is being made by a French company. The active material is contained in a bag of very thin gauze of an alloy, called "pontinium," and containing 15 parts of tin and 1 part of sodium per 1000 parts of lead. A cell of 100 ampere hours capacity has a total weight of 8.5 kg.

Miscellaneous.

Efficiency of Cement Kiln.—An interesting application of thermochemical methods to a problem of industrial chemistry is given in the calculation of the thermal efficiency of a rotary cement kiln, given by J. W. Richards in the January issue of the *Jour. Am. Chem. Society.* The test was made on a rotary cement burner, 60 feet long by 6 feet external diameter, fired by pulverized bituminous slack coal, at the plant of the Dexter Cement Co., at Nazareth, Pa. The ground cement mixture has the following composition: Silica 13.38 per cent, aluminium and ferric oxide 6.04 per cent, calcium oxide 41.96 per cent, magnesium oxide 1.53 per cent, carbon dioxide 34.65 per cent, moisture 0.43 per cent. The burnt cement clinker contains silica 21.27 per cent, aluminium oxide 6.42, ferric oxide 3.18, calcium oxide, 66.7, magnesium oxide 2.43. The kiln turns out an average of 3635 pounds of clinkered cement per hour from 5980 pounds of mixture fed to it, producing 200 pounds of flue dust. The coal used averages 110 pounds per barrel (of 380 pounds) of cement used. The author then gives a complete calculation of the different amounts of heat generated and consumed or lost, on the basis of 100 kg. of coal used, or 2 barrels of cement made.

The theoretical heating power of the fuel is 790.000 calories, while the combination of the ingredients of the cinder also evolves a large quantity of heat, equal to 142,819 calories, or 18 per cent of the heat developed by the combustion of coal. The heat in the clinker represents only about one-tenth of the heat developed in the kiln; this is a very low proportion for an industrial operation; and leaves large room for improvement and economies where fuel is dear. The great amount of heat carried out by the products of combustion and excess of air admitted, amounting to about two-thirds of the total heat developed in the kiln, points to great savings if a kiln of double length was used, and the amount of air admitted was reduced. The author finally estimates the temperature of the mixed gases of combustion and excess of air in the kiln at 1000°, while the clinker, leaving the kiln at 1200°, is hotter. The heat of combination of the ingredients of the cinder accounts for this apparent anomaly.

Resistivity of Glass Against Chemical Action.—A practical case in which wine, having been kept in bottles of unsuitable glass, deteriorated in quality, suggested the development of a method by which the examination of the resistivity of a glass bottle against chemical action could be easily and quickly made. F. Haber and H. Schwenke describe in *Zeit. f. Elektrochemie*, February 26, the following electrochemical method for this purpose. The bottle is carefully cleaned with cold water and is then filled with water free from carbonic acid, and air free from carbonic acid. is passed through it for about five hours at a temperature of 80° C. Every hour the current is measured between two small platinum electrodes, while a source of e. m. f. of 10, 20 or 30 volts is connected momentarily to the two electrodes. These three measurements of the current are combined for determining the specific conductivity, and from the change of the specific conductivity from hour to hour the progressing solution of the glass in water is found. To give a numerical value indicating the quality of the glass of the bottle, the rapidity with which the glass dissolves in water is compared with the corresponding value of standard bottles which have been tested once for all.

Thermometers from Fused Quartz.—In the *Zeit f. Elektrochemie*, February 26, C. Siebert discusses the manufacture of high temperature thermometers from fused quartz. Such thermometers, filled with tin, potassium, sodium, were found to be unsuitable, so that mercury had to be used again. Thermometers filled with mercury and nitrogen, under a pressure of 60 atmospheres enable one to measure tempratures up to 720° C., with exactness. The preparation of longer tubes from

fused quartz so as to have a uniform cross-section is still very difficult. These thermometers are now made in a length of 35 cm., the nickel steel scale reading from 300° to 750° C., each division representing 5° C.

Spectra of Elements.—In the *Zeit. f. Elektrochemie,* February 19, Runge discusses the regularities in the spectra lines of the elements. He describes what is meant with homologous lines of different spectra, and gives the rule that the logarithm of the atomic weight is a linear function of the distance of the pairs of homologous lines.

Potassium-Magnesium Carbonate.—In the *Zeit. f. Elektrochemie,* March 4, F. Auerbach discusses the physical chemistry of the double salt $MgCO_3.KHCO_3.4H_2O$, which is of importance in the Stassfurt potassium industry. The solubility of $MgCO_3.3H_2O$ in solutions of $KHCO_3$ of varying concentration was determined at 15, 25 and 35° C. Under proper conditions the above-named double salt is formed. The results are plotted diagrammatically.

Chemical Industries in Kansas.—An article on the manufacture of sulphuric acid and blue vitriol in Kansas is published in the *Lead and Zinc News* of March 21. There are two sulphuric acid plants, at Argentine and Iola, the method being essentially the same as in other works in this country. At Argentine there is also the only plant in the United States manufacturing blue vitriol by itself, and not as a byproduct, the process being that of Ottokar Hofmann.

Lead.—An article by R. N. Bell in the *Lead and Zinc News* of March 21 gives notes on lead mining in the Coeur d'Alenes district in Idaho. The gross lead and silver contents of the concentrates and crude ores shipped out of the district during 1903 were 213,520,000 pounds of lead, and 5,751,613 ounces of silver.

Biographical.—In the *Zeit. f. Elektrochemie,* R. Abegg gives an interesting account of the life and work of Svante Arrhenius, the famous founder of the electrolytic dissociation theory, and especially of the difficulties which he had to overcome to be recognized by the physicists and chemists in his native country, Sweden. A good portrait of Arrhenius is given.

Correspondence.

RADIOACTIVITY.

To the Editor of Electrochemical Industry:

Sir—I beg the opportunity through your pages of raising my voice as a chemist, in protest against the unqualified acceptance of the prevailing theory with regard to the ultimate cause of the extraordinary phenomena presented by the salts of radium.

The most popular hypothesis at present accounts for the various rays, the emanation and emission of heat, by the assumption that the so-called atom of radium breaks down with a development of energy 1000 times greater than the highest known development of energy by chemical process from a given weight of matter.

This hypothesis is not only entirely new, but it is also diametrically opposed to the universal law of chemistry, at least to the law which has until recently been regarded as universal, that the separating of chemical bonds always means the absorption of heat, and the formation of chemical bonds always means the development of sensible heat. There are, of course, apparent exceptions to this, where the compound in breaking up reunites with a great evolution of heat, but this evolution is not from the breaking up of the old bonds, but from the forming of new. At least, this is the theory which has been universally accepted and seems to be justified by experience and sanctioned by every rational consideration.

Here, now, we have a new theory, asking us to believe on indirect evidence, that a new force of energy 1000 times more potent has been found in a process which by analogy, would lead us to expect not the evolution of heat, but its absorption. Direct testimony in support of this hypothesis is conspicuous by its absence. The finest chemical scale, the most exact observation, fails to show the slightest loss of weight.

The whole subject of rays, other than the rays of light, has developed with such rapidity in the last ten years, and so widened the boundaries of our knowledge in directions that were hardly suspected hitherto, that it seems not only rational, but almost obvious that there must be many other forms of radioactivity, of which we, as yet, know nothing. The phenomenon of a body at a higher temperature than the medium which surrounds it, is as familiar as the fall of rain. It is true of almost any substance upon which the sun's rays are shining; may there not then be some kind of rays as yet unknown to us to which radium is more opaque than other substances, and by which it is stimulated into radioactivity and the development of sensible heat?

Here is a hypothesis that on the face of it, is in the first place not contrary to any known principle in chemistry or physics. Secondly, it is directly in line with a familiar phenomena both of the sun's rays and other rays. Cathode rays, as we know, seem to develop X-rays by contact with the walls of a glass tube.

If radium were itself the origin of the energy which it emits, why should solution in water temporarily deprive it of most of its power? If, on the other hand, it owes its peculiar properties chiefly to a certain opacity, there seems no reason why solution in water should not make it more permeable to some unknown ray, just as easily as it does to a ray of sunlight.

If, again, radium is itself the source of this energy, the energy developed ought to be directly proportionate to the weight of the radium, and the sensible heat ought to show great variation according to the mass of radium salts considered, and the shape in which they are assembled, for the escape of heat would naturally be proportionate to the surface, other things being equal, and a larger or more compact mass ought to show a higher temperature, than a small or thin mass, having a relatively larger surface.

If, on the other hand, radium is anything like as opaque to these rays as it is, for instance, to sunlight, the amount of energy developed would naturally bear a certain relation to the surface of the salts exposed to their action, but if it is only very slightly opaque, it seems likely it would require a considerable amount of radium to give us absolute proof on this point.

Far be it from me to imply that there may not be other explanations of these extraordinary phenomena, quite different from any hypothesis that has yet been broached, but I hope that this suggestion may lead to interesting experiments and further light on the subject. In this connection, let me quote from a world-famous chemist who was asked for advice on experimental work by a professor of Harvard College, and he answered "Probiren Sie Alles, sei es noch so dumm."

Godfrey L. Cabot.

Boston, Mass.

ELECTROLYTIC PRODUCTION OF HYDROXIDES AND OXIDES.

To the Editor of Electrochemical Industry:

Sir A synopsis of my patent, No. 748,609, for the "Production of hydroxides and oxides of the metals by electrolysis," appears on page 112 of your issue of March, 1904; your reviewer adds that he "experienced a great deal of trouble from the deposit sticking to the electrode on reversal of the current, causing a great increase in resistance and falling off in yield."

Of all the common metals whose oxides or hydroxides are in commercial use, I find that only one of them produces the effect your reviewer mentions (and I am at work to overcome it) either on a laboratory scale or in the actual com-

mercial production of them; and such a sweeping criticism, based on unsuccessful and abandoned experiments of "several years ago" is not only misleading to your readers, but a serious injustice to the patentee, and I respectfully protest against such criticism.

New York City. Fred. F. Hunt.

Current Notes.

Madison Local Section of the American Electrochemical Society.—The February meeting of the Science Club of the University of Wisconsin was held on February 23d, in the physical lecture room of Science Hall of the University Buildings. The Madison local section of the American Electrochemical Society was the guest of the club at this meeting. The following three papers were presented: Prof. C. F. Burgess discussed the electrolytic refining of iron by a method similar to copper refining. Since an enlarged paper by the author on the same subject will be presented at the Washington meeting of the American Electrochemical Society, we will report it at that time. Prof. O. W. Brown gave a general discussion of electric furnace designs and processes and Dr. Victor Lenher spoke on the solidity of gold. His paper will be abstracted in a later issue.

Electrochemistry at the Paris Exposition.—At the International Paris Exposition, to be held from August to November, 1904, at the Grand Palais des Champs-Elysées, a special hall will be devoted to electrochemical and electrometallurgical exhibits. The exhibits will be arranged according to nationalities, and each group will be divided into sections, according to the large industrial centers or to the water-power plants on which the industries depend. Communications should be adressed to M. Adolphe Minet, Directeur de l Electrochimie, 37 Rue de Berne, Paris.

Iridium.—A marked increase in the price of iridium, the second in commercial importance of the platinum group of metals, is reported to have taken effect during the past month. This fact is of particular importance to the electrical, chemical and dental industries, which are extensive consumers of the various alloys of iridium and platinum. Recent reports indi cate a very marked shortage in the supply of iridium, while the demand for this metal is rapidly increasing.

James Watt Memorial.—A memorial statue is about to be erected in Greenock, Scotland, on the site of the humble cottage in which James Watt was born. For this purpose subscriptions of small amounts—five dollars or less—are being solicited in various countries. Mr. Andrew Carnegie is chairman and Mr. Theodore Dwight, 99 John Street, New York, is secretary and treasurer of the American committee.

Case School of Applied Science.—The inauguration of Mr. Charles Sumner Howe as president of the Case School of Applied Science in Cleveland will take place on May 11. The inauguration exercises will be held in the Euclid Avenue Congregational Church. Before the inaugural address of President Charles S. Howe, the following gentlemen will deliver addresses: Dr. Worcester R. Warner, representing the board of trustees; President James B. Anzell, President Henry S. Pritchett, Mr. John R. Freeman and President Charles F. Thwing. An inauguration banquet will be held in the evening at the Hollenden.

The Use of Copper Sulphate in Algeria.—From a recent consular report we gather that sulphate of copper is extensively used in Algeria in viniculture. All of it is imported, the custom house statistics showing a total of nearly 2500 tons for the year 1902, although the yearly average is somewhat larger. The Algerian custom house statistics credit the United States with about 120 tons, although it is probable that the actual amount is much larger, owing to the goods coming through French entrepôts. The general opinion among purchasers in Algeria is that a much greater quantity could be exported to that country from the United States, provided it were sent by direct shipment in sufficient quantities to reduce freight. There is a demand for it in Algeria, and the American Consul suggests that exporters correspond with M. Buisson, secrétaire de la présidence du Tribunal de Commerce, Algiers, and also with the presidents of the chambers of commerce of Oran, Constantine, Phillippeville, and Bone. All communications should be written in French and prices quoted in French currency and metric weights.

FIRE PROOF WIRE

By William H. Easton, Ph. D.

Without question one of the most vital problems of to-day is to make the materials with which we come into constant contact resistant to the action of fire. Probably never before in the space of two months have greater calamities from fire occurred than we have witnessed this year, proving equally the failure of our present methods of fireproofing and the need for more effective ones. There is no question that electricity should come in for its share of consideration and improvement, and that electrical machines and electrical conductors should be as entirely without the power of burning as a steam pipe. It is indeed a curious example of the unfitness of things when we find electrical conductors covered with such inflammable materials as cotton, silk, rubber, paraffin, etc.

The only successful covering for wires to be used in coils for machines, etc., is a double map of cotton, and this is rendered dry and firable at a temperature slightly above the boiling point of water, and it needs but a slight sparking, a trifling overload, or one of many accidents so familiar to electrical men to cause this to char, become conducting, form a short circuit, and set the whole apparatus in a blaze. Then rewinding, costly and time-consuming, must take place, and the knowledge remains that the same may occur at any moment. This has reacted powerfully upon electrical machinery in general, and is one of the greatest stumbling-blocks in the way of electrical progress. What is true of dynamos and motors is true of all electrical devices employing coils or windings of any description, and the care of that delicate material weighs the most heavily upon the electrical man's shoulders.

There is another and possibly a more important consideration. Every house, every building, every factory that employs electricity is penetrated in every direction with heavy wires to carry the current. Examine a piece of this wire, with its several cotton braids and waterproofing of rubber or paraffin composition, and then touch a lighted match to it, and watch the flame creep along and the burning drops fall. How safe would one feel should a break or piece of careless wiring or a slight irregularity in the circuit cause such a blaze to spread in every direction in contact with woodwork and wall paper. Defective insulation is responsible for great losses of life and property, but we continue to polish the stove with coal oil and trust to luck.

While all other conditions for insulation have been successfully fulfilled, the force of heat has as yet remained unmanageable. A temperature of 150° C. is sufficient, if maintained, to render useless every insulation at present used upon wires, and it is especially necessary to overcome this difficulty.

These are some of the considerations that have called the Heany Fire Proof Wire into existence, and to fill the gap still left open, an entirely new departure in insulation has been taken. The wire is insulated by first covering it with a fine even web of asbestos, which is then passed through a paste of cement that upon heat and pressure forms a uniform, homogenous mass, uniting wire and fibre, together chemically, and forming a smooth white, almost porcelain-like covering. This

insulation is very strong and flexible, so that it will resist abrasion and will not peel, crack or twist off. Weathering does not affect it, and short of being directly immersed in water it is moisture proof. It can be made of any desirable thickness from but slightly heavier than writing paper up to cable sizes. Its most important feature is its resistance to heat, in which respect it is practically indestructible for being composed entirely of mineral matter, it cannot burn, and will withstand temperatures that will cause the copper within to melt without breaking down. A coil in Mr. Heany's laboratory at York, Pa., has been heated to bright redness many times by a powerful alternating current and still remains as good as ever. This demonstrates that no accidental overload can injure the machine and makes the fusing point of the metal and the safety of the building the considerations in determining the factor of safety. This also allows much smaller wire to be used in machines, thus reducing the first cost and the size, and producing a reliable machine instead of a rather dubious and delicate piece of mechanism.

For line wire, this insulation is covered with a protecting braid and the whole treated with a water-proofing composition that is entirely fireproof also, so that the danger from burning wires is entirely obviated. It is not so much the heating of the wire, nor the sparks or arc formed by a break or short-circuit that cause fires to start, but it is the subsequent blazing of the insulation that has been so destructive, and this cannot take place with the Heany wire.

WATER-WHEEL GOVERNORS.

On account of the importance of cheap power for electrochemical industries, and for the further reason that we have in the United States a number of large water powers just where they are wanted—*i. e.*, not on remote, out-of-the-way spots, but at places suitably located for shipment of the goods—there has been, as is well known, an intimate connection between the evolution of certain large electrochemical industries and the development of water powers in this country. Niagara Falls is the example par excellence, illustrating this development. However, there are also smaller hydroelectric plants in connection with metallurgical works in mountain districts. This development may be safely expected to go on with greater energy in future, since the advantages of the use of electric power and lighting for mining and metallurgical plants is now well understood; this will at the same time encourage the introduction of electrochemical methods in metallurgical works.

Under these circumstances the principal requirements of hydraulic plants are of great interest to electrochemists and metallurgists. It is a fact that the electrochemical or electrometallurgical engineer in his work is often confronted with troubles resulting from an insufficient regulation of the power supply. In water power plants a detail, though small, yet of great importance, is the water-wheel governor. For this reason the following notes on the water-wheel governors, made by the Lombard Governor Co., of Boston, Mass., should be of great interest to our readers.

All of the governors made by this company consist primarily of a hydraulic piston which applies its thrust in either direction to the water-wheel gates in the act of opening or closing them. The piston rod terminates in a rack which is geared positively to the gate shaft. One complete stroke of the governor piston entirely opens or closes the water-wheel gates; consequently, any motion of the governor piston, less than a complete stroke, causes a correspondingly smaller motion of the gates. For example, if the governor piston moves one-half its complete travel, it will one-half open or close the water-wheel gates. If the governor piston moves one-tenth its full stroke, it opens or closes the gates one-tenth.

The above action may be seen in a general way from Fig. 1, which illustrates the type F governor of the Lombard Co. This governor, which is the simplest in construction, and smallest in size made by them, is adapted to regulating Pelton and all forms of impulse or tangential water-wheels. It will be seen that its piston terminates in a rack which rotates a gear. The central shaft of this gear sector is coupled directly (or, if that is not possible, is geared) to the rock shaft controlling the deflecting nozzle; or, if this governor is used to regulate a small turbine, the central shaft of the gear sector is coupled directly, or through gearing, to the gate stem. Thus, it will be seen that, as the piston travels in or out, the nozzle will deflect the water off from or on to the water-wheel or open or close the gates of the turbine, as the case may be.

If, for example, the piston is capable of moving through its entire stroke in two seconds, it follows that the water-wheel gates will be opened or closed in two seconds; and any correspondingly smaller gate movement will be made in a correspondingly smaller space of time. It is theoretically true, and it has also been amply demonstrated in practice, that the quicker the water-wheel gate is moved to the correct position after a load change occurs, the smaller will be the speed variation. The Lombard Governor Co. builds governors of a number of sizes, and in practice selects one with a piston of such a size that it is capable of moving the gates through their

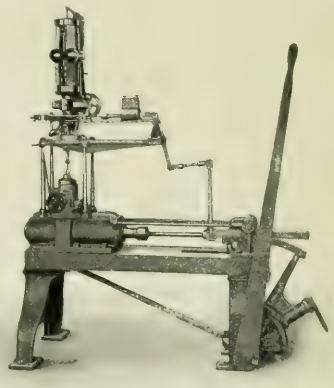


FIG. 1.—WATERWHEEL GOVERNOR.

entire range in two or three seconds. If it is found for any reason—as, for example, weakness of the flume or wheel case—that the gates cannot be safely handled so quickly, then the governor may be adjusted to move as slowly as required.

In the governor shown in Fig. 1 the hydraulic piston is moved by water under flume pressure. There is a pipe-threaded orifice under the bed of this governor, and this is connected directly to the flume. Therefore, this type of governor is adapted to high head-plants in general, or to such low-head plants in which a small amount of water is available under high pressure. Where the water wheels operate under low head, or where there is no water available under high pressure, a type of governor is used in which the piston is moved by oil under pressure. Fig. 2 shows Type D governor. This governor operates with oil under pressure as above referred to.

It will be observed that under the bed of the governor is a cylindrical tank. This is divided into two parts by a tight partition, the location of which may be seen from the row of rivet heads. The larger part of the tank (to the left in Fig. 2) is about half full of oil. The upper half of this pressure tank contains air under about 200 pounds pressure to the square inch. The smaller end of the tank (to the right in Fig. 2) contains a vacuum. The pressure and vacuum are constantly maintained by a pump located on the farther side

of the head of the governor, and driven by the larger pulley shown, which is belted so as to slowly rotate all the time the governor is in operation.

When the governor piston moves the water-wheel gates, it is because oil from the pressure tank is let in on one side of the piston; simultaneously the oil on the other side of the piston is vented into the vacuum tank from whence it is immediately pumped into the pressure tank.

Fig. 3 shows the top of one of the governors of the Lom-

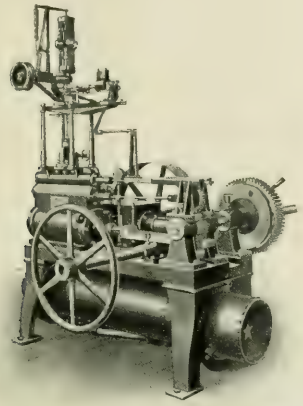


FIG. 2.—WATERWHEEL GOVERNOR.

bard Co.; it is through this mechanism that the governor is made to open or close the water-wheel gates when the load varies and the speed tends to change. All governors of the company are fitted with practically the same top, the action of which may be briefly described as follows.

The pulley shown in Fig. 3 is belted directly to the water-wheel shaft and drives the governor balls which, when rotating at normal speed, stand out considerably from the axis of rotation. The mechanism is such that as the balls spread out, under the action of centrifugal force they depress the top plate into which the flat springs supporting them are inserted. This top plate is attached to a rod which passes down through the hollow vertical shaft, carrying the balls, and terminates in a small vertical piston valve located behind the hand-wheel shown near the bottom of the cut.

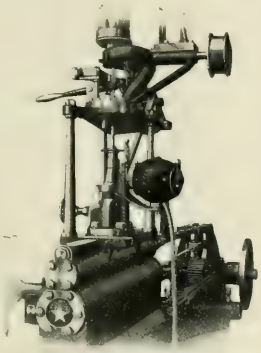


FIG. 3. WATERWHEEL GOVERNOR

It will be seen therefore, that, as the balls fly out under the influence of increased speed, they will depress the piston valve and, conversely, as they travel inward when the speed becomes below normal, they will lift it. The valve stem or rod above referred to is of such length that when the balls are in the position due to normal speed, the valve is closed; but the moment when the speed becomes above or below normal, the piston valve admits oil or water, as the case may be, to one side or the other of the main piston of the governor. This causes it to open the water-wheel gates if the speed is below normal, or close them if the speed is above normal.

As the rotating balls are exceedingly sensitive, and as the piston valve has an extremely small lap, the least change in speed of the water-wheel causes the governor to open or close the water-wheel gates.

It should be remembered that not only do the governor balls possess the property of inertia, and fail to instantly respond to changes in speed, but also that the water, as it approaches the water-wheel possesses the same property in a marked degree, and hence the water-wheels do not respond instantly to changes of load, so that the governor balls do not feel the changes in load instantly. It is therefore evident that the governor top must be of such design that it will move the gates to the correct position for any change in load irrespective of the momentary speed of the water-wheel. For example, if one-half the load on the water-wheel were instantly thrown on or off it does not follow that its gates should at once be moved to a position corresponding to one-half more or one-half less load. The governor should as quickly as possible move the gates to such a position that the water, *at the velocity which it has at that instant of time*, will turn the water-wheel at its normal speed and then as the water gradually assumes the new velocity called for by the new load, move the water-wheel gates to their normal position for normal speed at normal water velocity. It would not be appropriate in this article to enter into a complete description of how this is accomplished. The makers, however, emphasize the fact that in their governor tops all possible adjustments are made to overcome the tendency of the water-wheel to race. Speed recorder strips, obtained in practice, prove that they have been successful in this all important matter.

Governors made by the Lombard Governor Co. are built in twelve standard types adapted to various conditions; they also build special governors for exceptionally large units, and at present are constructing a special governor to develop 100,000 foot pounds in two seconds, to regulate the largest water-wheel now in existence.

Their electric speed controller which may be attached to all types of governors made by them, permits of starting and stopping the water-wheels from a distant point, as, for example, from the switchboard. This device also makes it possible to adjust the speed of the water-wheels with the utmost accuracy, and is of especial advantage in paralleling alternators. All told, their governors are used to regulate about half a million horse power of water-wheels in this country, in addition to a large number of installations abroad. Their shops, which are located in Boston, are equipped throughout with the most modern machinery, and all governors are built with interchangeable parts.

FILTER PRESSES.

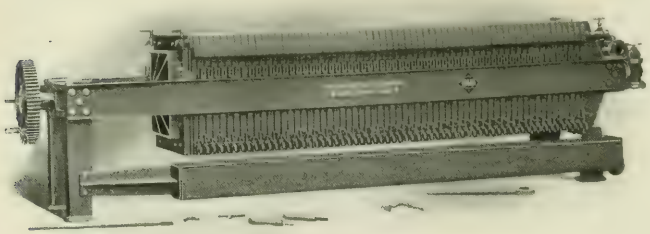
We herewith illustrate one of six filter presses supplied by the Niles Tool Works, Hamilton, Ohio, to a gold mine in the State Chihuahua, Mexico, for the cyanide treatment of slimes. It possesses some interesting features made necessary by the location of the mine, to which the machines had to be brought by mules. No piece, therefore, exceeds the limit of weight admissible for this method of transportation (300 to 325 pounds). The fixed head, accordingly, had to be built in cast-iron sections, while the sliding head is made up from steel plate. The side bars are made of a deep section of channel bar, and the filtrate trough is of sheet steel for lightness. The filter presses are provided with a double washing arrangement, giving the concentrated washings so desirable in cyanide extraction, and the whole plant has been in satisfactory operation for some time.

In this connection some general notes on the construction and uses of filter presses may be of interest. One of the most frequent and most important operations in all chemical industries is the separation of liquids from solid matters suspended in them, whether the object be to recover the pure liquid or

the solid matter, or both. Filter presses have found an extended application in various chemical industries for this purpose, their advantages being easily explained by their construction.

A filter press consists in principle of a number of chambers bounded by filtering material, most of cotton cloth. These chambers may be formed in two ways. Either plates are used with recessed faces, the recesses in adjoining plates together forming the chamber, or flat plates are used, alternating with frames of the desired depth. In either case the plates are provided with vertical grooves or both vertical and horizontal grooves, both sides being covered with filter cloths. The plates and frames are clamped together between two heads of a strong screw lying in the axis of the press. The two types are commonly distinguished as the chamber press, and as the frame press.

All the plates, and one head, are provided with a hole in the center, and similar holes are made in the filter cloths, a joint being made between the cloths and the plate by suitable unions. A continuous feed channel through the whole press is thus formed and the liquid to be filtered enters through this channel under pressure, fills all the chambers, and is then forced to pass through the filter cloths, leaving suspended solid matter behind, which gradually fills the chamber. The clear liquor passes down the corrugations on the faces of the plates, and finds its way through a channel, which connects the vertical



FILTER PRESS

grooves and leads into an outlet port. Filtration continues, with a gradually rising pressure, until the whole chamber is filled with a solid cake. The feed is then cut off, the press is unscrewed, and the plates are separated. The cakes of solid matter drop out, the press is screwed up and is then ready for another operation.

The efficiency of the filter press is due to the very large filter area in a comparatively small space and to the use of high pressures which permit rapid filtration.

Of the two types of filter presses, the chamber press is the cheaper one, since it has only half the number of joint faces as the frame press. The chamber press has the further advantage that as soon as the press is opened and the plates separate, the cake drops out. The feed channel being large and central, there is very little risk of its being clogged, even with heavy materials.

In the frame press the feed channel is generally placed in flaps outside the joint of the plates and frames, so that a larger filtering surface is obtained and the cloth unions are avoided. On the other hand, the ports leading from the passage into the chamber, are more easily clogged by heavy material than the central channel of the chamber press. When the frame press is opened, the cake remains in the frame and this type is, therefore, obviously unsuited when the material does not form a solid cake.

To get the best results in any particular case, it is necessary to choose the proper depth of chamber, which, of course, determines the thickness of the cake. This size depends entirely on the material, and is a matter for experiment. As long as a cake still allows liquid to pass through it without excessive pressure, so long filtration will continue. Some materials will form cakes up to 3 and 3½ inches thick, but for general purposes, the depth of the chamber may be chosen as 1½ inches in most cases.

After filtration, another operation may be performed to which the filterpress lends itself readily, namely, that of washing out the cakes with water or some other solvent, so as to remove the last traces of the mother liquor from them. For this purpose a channel is provided similar to the feed channel, but with ports into alternate chambers only, leading into the corrugated surface behind the filtercloths. Water or any solvent is admitted and the outlets on the plates having inlet ports for the above, are closed. The washing water is thus forced to fill all the grooves, to pass through the entire thickness of the cake, through the opposite filter cloths and out through the outlet passages in alternate plates. Air outlets are provided at the top of the chambers, so as to allow the water to reach the entire surface of the cake. Washing is finished when no more soluble matter passes away with the wash water; this is easily controlled by means of a hydrometer in the delivery pipe. When necessary, the cakes after washing may be dried by passing through them compressed air or superheated steam, in the same way as the wash water.

The material of which the press is made depends somewhat on the purpose for which it is to be used. Unless the nature of the liquid under treatment permits it, cast iron is employed for the plates; otherwise tinned or galvanized cast-iron plates are used or gun-metal or phosphor bronze, if necessary. In some cases it is necessary to use wooden plates, made of pine or oak, for instance, in aniline or alizarine dye works.

For every purpose it is necessary to use the proper filter cloth. To get the best cloth is a matter of experiment. The cloth must be of sufficiently close texture to retain all the solid particles, yet not closer than necessary, so as not to obstruct the flow of the clear liquid and retard filtration. In many cases two cloths of different texture have to be employed. The Niles Tool Works at Hamilton, Ohio, have special apparatus by which they carry out experiments for determining for their customers the most suitable kind of cloth for different purposes. The material for filter cloths is usually cotton; where this is not applicable, pure wool (for acids) or asbestos is used.

The feeding of the filterpress is also a matter deserving close attention. As soon as the turbid liquor is admitted a film of solid matter is deposited on the surface of the cloth, and this film then really acts as the filter, while the cloth serves as support for the film. It is essential that this solid matter should not be driven in the pores of the filter cloth, and the pressure must, therefore, be put on, increased gradually and violent fluctuations avoided. Presses may be fed by suitable pumps or by means of compressed air. The Niles Tool Works have paid special attention to the latter method, which avoids all the trouble caused by the valves and plungers of pumps pumping thick liquid, and provides at the same time a ready means for drying the cakes.

Library of Union Engineering Building.—The libraries of the Institutes of Electrical Engineers and Mining Engineers, and of the Society of Mechanical Engineers, which will be assembled in the Union Engineering Building, will commence with about 50,000 volumes, many of them of inestimable price.

INDUSTRIAL NOTES

We have received from Messrs. Foote, Pierson & Co., New York City, their catalogue 11 of electrical measuring and scientific apparatus, which contains illustrated descriptions of their condensers, galvanometers, bridges, resistance boxes, standard resistances, compensation apparatus, standard cells, cable-testing sets, X-ray tubes, photometers, voltameters and ammeters.

"Appert" Glass.—The Scientific Materials Co., of Pittsburg, Pa., has recently issued an illustrated pamphlet on "Appert" glass, which, by reason of its composition and method of manufacture, can be made into vessels of any symmetrical shape possessing unusual strength and resisting perfectly the action of acids, electricity and climatic changes. Such Appert glass vessels are rapidly supplanting containers heretofore made of clay, wood, metal, etc. They are practically indestructible, are easily cleaned, and the contents are always in full view.

The Power and Mining Machinery Co., of New York City, have received orders from the Amparo Mining Co., of Philadelphia, for one 190-hp., and two 130-hp. Crossley gas engines, and six Loomis generators, with two 10,000 cubic foot holders, also mining machinery, consisting of crushers, Brückner roasting furnaces, condensing chambers, etc. The same company has received an order from the Nogales Copper Co., of Chicago, for installation in Mexico, for three 330-hp. Crossley gas engines, from Loomis-Pettibone gas generators, one 10,000 cubic foot holder and one 5000 cubic foot holder. This contract also includes the mining machinery for the plant.

We have received from the Crocker Wheeler Co., of Ampere, N. J., bulletin 40 on crane motors and flyers; 144 (rehabilitation of a flooded power plant at Kansas City), 145 (electric drive for machine tools, with methods of variable speed control), and 153 to 168 (various examples of machine tool equipments, such as motor drive for band saw, band saw setting and filing machine, 3-inch, bolt cutter, 30-inch drill press, four-spindle mud-ring drill, 24-inch lathe, gap lathe, with 28 and 48-inch swing, heavy turret lathe, light and heavy milling machine, gear shaper, horizontal boring machine, 51-inch boring and turning mill, punch, rotary bevel shear, plate-bending rolls).

The Laboratory and School Supply Co., who have recently opened a New York office at 20 to 24 East Twentieth Street (as a branch of the Vereinigte Fabriken für Laboratoriumsbedarf, a consolidation of the firms of Dr. Peters & Rost and Max Kaehler & Martini of Berlin, Germany), have sent us their very complete and fully illustrated catalogues of chemical apparatus and instruments, and their special list of electrochemical apparatus. The latter deals with apparatus for generating current (galvanic cells, storage batteries, thermo couples, dynamos), conductors and accessories (switches, rheostats, etc.), measuring apparatus for laboratory work and special apparatus for electrochemical work, such as electrolytic cells, electric furnaces, induction apparatus and apparatus for electroanalysis.

Data on Insulating Materials.—Under this title the Dielectric Manufacturing Co., of St. Louis, Mo., has issued a neat pamphlet containing diagrams with the following important curves: Break-down potentials in air as function of length of air-gap, dielectric strength of solid and pasted mica curves showing the importance of the time element in applying potential to breakdown insulating materials, curves showing the importance of drying and varnishing sheet insulating materials, curves showing the dielectric strength of different sheet insulating materials compared with oil and mica, a curve showing the great decrease in insulating qualities of transformer oil by presence of small amounts of water, and curves showing permanent insulating qualities of "dielectrol" (an insulating compound made by this company) when in continued contact with copper on the inside of coils.

Insulating Covering for Cables to Prevent Fires.—The dangers from cable fires are well known. When the wires in a cable are overheated, the insulating compound frequently melts and brings two adjacent uncoated wires together. This creates a short-circuit, with the consequent burning and fusing of the wires. This sets fire to the insulation, as well as to the outer coating or wrapping, which is usually of cotton braid. The fire is thus communicated to the next cable, and so on. To prevent such accidents which may cause enormous damage, the H. W. Johns-Manville Co., of New York, have devised an insulating covering for the cables, which so fire-proofs these cables so as to prevent, in case of short-circuiting of one, the ignition of the others. It was first used by the Niagara Falls Power Co., hence its name, "Niagrite." Niagrite is bound spirally about the cable to be protected. The composition will dry out under ordinary conditions in about twenty-four hours and become very hard and absolutely fire-proof.

Aluminothermics in the United States.—In a test of thermit, made by the Pennsylvania Railroad Co. in Altoona, the riser from the weld of the steel frame was drawn out under the hammer into a bar some 3 feet long and turned down and broken. The analysis of the metal is as follows:

Carbon	0.102	per cent
Manganese	2.330	"
Phosphorus	0.070	"
Silicon	1.227	"
Sulphur	0.034	"

The following was the result of the physical test:

Tensile strength in pounds per square inch, 91,600.
Elongation in 8 inches, 21.5 per cent.
Appearance of fracture, silky.

An engine, the frame of which was repaired with thermit about the 20th of February, has been on the road ever since. The thermit used for this weld had in it a mixture of 2 per cent pure manganese, free from carbon, and 5 per cent iron punchings.

Pipe Covering Tests.—In a recent bulletin of the H. W. Johns-Manville Co., of New York City the results of pipe covering tests are given which were made in England, and in which the asbesto-sponge felted section covering of the H. W. Johns-Manville Co. was compared with some other coverings. F. M. Long, city electrical engineer of Norwich, found that the amount (in pounds) of steam condensed per hour in 12 feet of 3-inch wrought iron pipe (3.55 inch external diameter) with different coverings was as follows:

Asbesto-Sponge Felted Section Covering, 1 inch thick	1.82 lb.
Magnesia Sectional Covering	2.38 "
Asbestos Composition	2.51 "
Mica Composition, put on 1½ inch thick, but reduced in dry to 1¼ inch thick	3.17 "

The steam pressure was 180 pounds, and the temperature of the room from 70° to 79° Fahrenheit. A radiation test was made by Frank Ayton, chief engineer of the Ipswich Corporation Electric Department, the steam pressure being 156 pounds. With asbesto-sponge felted section covering, of 1⅛-inch thickness, the surface temperature was 149° F., with mica composition of 1¾-inch thickness, 179° F.

DIGEST OF U. S. PATENTS

Prior to July, 1902.

Compiled by Byrnes & Townsend, Patent Lawyers, National Union Building, Washington, D. C.

The Production of Aluminium from Molten Electrolytes.

244,234. July 12, 1881. Paget Higgs, New York, N. Y.

Melts ores of aluminum, copper, magnesium, chromium,

platinum, iron, etc., with borax, boracic acid or silica, to form a borate or silicate, and electrolyzes. For example, melts cryolite and borax in a clay crucible at a temperature of 1000° C., lowers to 900° C., and electrolyzes. The aluminium is deposited in globules which are united by again raising the temperature to 1000° C. Mentions the electrolysis of copper borate, iron silicate and iron slag.

315,266. April 7, 1885. Moses G. Farmer, New York, N. Y.

Electrolyzes molten chlorides or fluorides of aluminium, or double haloids of aluminium and ammonium or sodium. Cathode vessels of aluminium or platinum; anodes of carbon or aluminium. May employ a group of three depending anode rods with means for rotating them to stir the bath. A number of cells are connected in series, each vessel having an integral extension which is secured to the anode of the next cell.

362,441. May 3, 1887. Richard Gratzel, Bremen, Germany.

Reduces aluminium from its single or double fluoride, *e. g.*, cryolite, by magnesium, calcium, barium or strontium. May fuse the fluoride and stir in solid or molten magnesium, or lead in magnesium vapor by a tube; or magnesium may be liberated in the bath by electrolyzing the fluoride mixed with (1) magnesium chloride in the proportion of three equivalents to one of fluoride; (2) potassium mabnesium chloride or sodium magnesium chloride, as carnallite; or (3) calcium, barium or strontium chloride. May introduce copper or use a copper cathode to produce an aluminium copper alloy.

387,876. August 14, 1888. Paul Heroult, Lauffen-Uhwiesen, Switzerland.

Electrolyzes molten alumina, without flux, using a molten cathode of copper or iron. May thus produce aluminium bronze, ferro-aluminium, aluminium-steel, aluminium-brass, etc. Cathode vessel of carbon, surrounded by powdered carbon and inclosed in masonry. Anode of carbon. E. m. f., 20 to 25 volts.

400,664. April 2, 1889. Charles M Hall, Oberlin, Ohio.

Electrolyzes alumina dissolved in molten potassium aluminum fluoride, $K_2Al_2F_8$. May add or substitute for part of the potassium fluoride, lithium fluoride. For example, may use $KLiAl_2F_8$ or $K_2Li_2Al_4F_{18}$, conveniently produced by neutralizing aluminium hydrate and potassium or lithium carbonate with hydrofluoric acid. These baths are of less specific gravity than aluminium, which sinks to the bottom. Cathode vessel, steel or copper lined with carbon. Anode, platinum, or copper which becomes coated with a protecting layer of oxide. E. m. f., 3 to 4 volts.

400,665. April 2, 1889. Charles M. Hall, Oberlin, Ohio.

Electrolyzes alumina or bauxite dissolved in molten calcium aluminium fluoride, $CaAl_2F_8$, or $Ca_5Al_2F_{12}$; or may employ the corresponding salts of barium or strontium. The deposited aluminium rises to the top of the bath, but may be alloyed with iron or copper at the cathode to produce an alloy which is heavier than the bath. Or potassium aluminium fluoride, $K_2Al_2F_8$, may be added to about two-thirds the weight of the original bath, to give a bath lighter than aluminium. For the production of pure aluminium, uses carbon electrodes and a covered vessel with a lining of carbon. A carbon partition may depend between the electrodes. A floating layer of alumina is employed on the cathode side of the bath to exclude air.

400,666. April 2, 1889. Charles M. Hall, Oberlin, Ohio.

Electrolyzes alumina or bauxite dissolved in a molten mixtureture of sodium aluminium fluoride, $Na_2Al_2F_8$, and calcium aluminium fluoride, $CaAl_2F_8$, produced by melting together calcium fluoride, 234 parts, cryolite, 421 parts, and aluminium fluoride, 845 parts. Three to 4 per cent of calcium chloride is added to prevent the bath from thickening in use. Aluminium sinks in this bath. E. m. f., 6 volts.

400,667. April 2, 1889. Charles M. Hall, Oberlin, Ohio.

Electrolyzes alumina dissolved to saturation in a molten bath of calcium fluoride, 234 parts, cryolite, 421 parts, and aluminium fluoride, 845 parts, plus 3 to 4 per cent of calcium chloride For the production of pure aluminium, uses a carbon cathode; for alloys, one of iron, copper, etc. E. m. f., 4 to 8 volts. Dips out the aluminium by a ladle covered with carbon. Increased resistance in the bath and a high percentage of carbon monoxide relative to carbon dioxide evolved at the anode, indicates too low a percentage of calcium chloride.

400,766. April 2, 1889. Charles M. Hall, Oberlin, Ohio.

Electrolyzes a solution of alumina in sodium aluminium fluoride, $Na_2Al_2F_8$, produced by melting cryolite, 421 parts, and aluminium fluoride, 338 parts. May use a solution of alumina in potassium aluminium fluoride, $K_2Al_2F_8$. Anode, platinum, carbon, or copper which becomes coated with a layer of oxide. To render the bath more fusible, an equivalent of lithium fluoride may be substituted for one-fourth of the sodium fluoride.

464,933. December 8, 1891. Charles S. Bradley, Yonkers, New York.

Melts and electrolyzes ores, *e. g.*, cryolite, by the same electric current. The molten bath may be held in a cavity in a mass of the ore, or on a bed of carbon and surrounded by a wall of the ore, in which case the carbon bed may serve as an electrode. The ore may be held in a brick receptacle or placed on a brick hearth.

466,460. January 5, 1892. Thomas A. Edison, Menlo Park, New Jersey.

Electrolyzes molten volatile substances, *e. g.*, aluminium chloride, by maintaining them under pressure, which may be produced by confining the evolved chlorine or other gas. Vessel, iron or nickel, which may be lined with fire-clay. Cover, several layers of mica, bolten onto the vessel and supporting the electrode.

468,148. February 2, 1892. Charles S. Bradley, New York, N. Y.

Same as 464,933, except claims.

473,118. April 19, 1892. Paul Héroult, Lauffen, Switzerland.

Electrolyzes molten alumina or clay. E. m. f., 12 to 15 volts. May use a molten copper cathode, producing a silicon-aluminium-copper alloy. Alumina and copper fed in during the operation. Anode, a bundle of carbon plates, interleaved with metal and bound by clamps; automatic feed, controlled by an ammeter. Cathode vessel, carbon with an iron shell cast around it. Brass or copper terminal studs pass through the shell into the carbon. The vessel has a tap-hole with a spring-pressed carbon stopper, and is covered with a graphite plate or bricks, having covered feed openings. A filling of graphite powder is interposed between the edges of the cover and the iron casing.

473,866. April 26, 1892. Charles S. Bradley, Yonkers, New York.

Electrolyzes ores, *e. g.*, cryolite, by placing carbon electrodes horizontally in a heap of the ore, and directing a blow-pipe flame upon the apex or top of the heap until a pool of molten ore collects around the ends of the electrodes. The ore may be contained in a receptacle, or simply piled in a heap upon a brick hearth.

476,256. June 7, 1892. Michael Emme, Atlanta, Ga.

Electrolyzes alumina, previously calcined and dissolved while hot, in a molten mixture of aluminium fluoride, 10 parts, and aluminium chloride, 1 part. Cathode vessel, cast-iron with a lining of retort-carbon insulated from the iron by a paste of asbestos and bauxite. The vessel has a tap-hole containing a carbon cock. Anode, a group of ten or fifteen depending carbon rods, hung in concentric circles by terminals clamped in lateral recesses in the radial bent arms of a vertically adjustable copper spider.

Electrochemical Industry

VOL. II. NEW YORK, MAY 1, 1904. No. 5.

Electrochemical Industry

Published on the first of each month by the
ELECTROCHEMICAL PUBLISHING COMPANY,

[*Incorporated.*]

114-118 LIBERTY STREET, NEW YORK.

J. W. RICHARDS, PH. D. ..... *President.*
E. F. ROEBER, PH. D. ..... *Editor.*

Telephone Call: 7607 Cortlandt.

Subscription Price: $2 per year, postpaid to any part of the world. Single copies 25 cents.

ADVERTISING RATES GIVEN ON APPLICATION.

Copyrighted, 1904, by the Electrochemical Publishing Co.

Entered as Second-Class Matter, June, 1903, at the Post-Office at New York, N. Y., under the Act of Congress, March 3, 1879.

CONTENTS.

Editorial 167
Faraday Society Meetings 170
The Chemical Engineer 171
Washington Meeting of the American Electrochemical Society 173
Standard Cells. By F. A. Wolff 174
Preparation of Materials for Standard Cells and Their Construction. By H. S. Carhart and Geo. Hulett 176
Single Potentials of the Halogen Elements. By William Roy Mott. 177
The Continuous Advance in Electrochemistry. By J. W. Richards. 177
The Composition and Resolution of Voltages. By J. W. Richards. 178
Molecular Conductivity. By C. J. Reed 179
The Economic Balance in Electrolytic Copper Refining. By Lawrence Addicks 180
Heat of Neutralization. By G. W. Westman 181
The Energy of Ions. By Louis A. Parsons 182
Aluminum Electrolytic Condenser. By C. I. Zimmerman 182
Study of the Electric Arc. By William S. Weedon 183
Copper Voltameter. By Isaac Adams and Barry MacNutt 183
Electrolytic Iron. By C. F. Burgess and Carl Hambuechen 184
The Reduction Temperature of Zinc Oxide. By Woolsey McA. Johnson 185
Electrolytic Preparation of White Lead. By C. F. Carrier, Jr. 187
Osmotic Pressure and Alternating Current. By William H. Davis. 187
Manufacture of Ferro-Nickel from Pyrrhotite. By Ernst A. Sjostedt 188
The Electric Furnace in Metallurgy 188
Electrochemistry at the University of Wisconsin. By C. F. Burgess. 189
Current Notes 197
Synopsis of Articles in Other Journals 198
Analysis of Current Electrochemical Patents. By Geo. P. Scholl. 203
On the Combination of a Solvent with the Ions 207
Correspondence: Electrolytic and Zinc Precipitation of Gold from Cyanide Solutions. By Chas. Butters 207
Ferro-Nickel from Pyrrhotite. By Ernest A. Sjöstedt 207
Arsenic in Copper Refining. By Woolsey McA. Johnson 207
Book Reviews 208
Carbon Brushes for Dynamos 208
The Measurement of Gold and Silver Buttons in Quantitative Blow-Pipe Analysis 208
Direct-Current Electric Mining Hoist 209
Acid Pumps 209
Industrial Notes 210
Personal Notes 210
Digest of United States Patents Prior to July 1902. By Byrnes & Townsend 210

WASHINGTON MEETING AMERICAN ELECTROCHEMICAL SOCIETY.

In our last issue we predicted that the Washington Meeting of the American Electrochemical Society would be the most enjoyable and the most numerously attended gathering of this vigorous and active society. Our prediction has turned out to be only half true. The meeting was certainly highly profitable and enjoyable, but in spite of the attractions of Washington in springtime, and in spite of an excellent programme arranged by the local committees, the attendance did not nearly come up to expectations. There is, however, nothing discouraging in this fact. Most of our flourishing national engineering societies have gone through the same experience; they have first held more than one general meeting a year, but have finally concluded that this is bad policy. To hold one general meeting, besides frequent local meetings, is now almost uniform practice. While not ideal, this arrangement takes at least the practical situation into account. The United States is a large country, and an engineering society has members in all its parts, and for a great many of the members the time and expense to be incurred in traveling to a distant place of meeting, make it desirable that the work of the society should be concentrated in one annual meeting. Then, everyone who wants to meet his professional co-workers once a year will attend this meeeting. With two meetings, one has the choice and some will attend the first, some the second meeting, and the principal object of a general meeting to bring all together will be defeated

On the other hand, it cannot be denied that the American Electrochemical Society has held and holds a unique position among the other national societies. Its first meeting in Philadelphia in April, 1902, set a standard which has been fully sustained in its later career; with respect to attendance and quality of the professional proceedings, no meeting of the American Electrochemical Society so far held needs to fear comparison with its older and larger sister societies. But above all, it was the spirit of youth, of aggressive youth, which has characterized the work of this society. The true *esprit de corps* which now unites the electrochemists and electrometallurgists of this country and binds together engineers and scientists, is one of the most splendid achievements of the work of the society, and the spirit of good fellowship made every one of its meetings memorable. The Washington meeting was no exception

And after all is said for one versus two general meetings a year, we must not forget that the present year is an exceptional one, on account of the St. Louis Exposition and the Inter-

national Electrical Congress and Chemical Congress, to be held in connection with it. The Electrochemical Society will hold its next meeting during the week of the Electrical Congress, and there is no doubt that many of its members are sparing their energies for this purpose, since they will have there an opportunity to impress their ideas on a wider and more general public. Everyone of our electrochemists and electrometallurgists is a pioneer, and to accomplish new results he has to break into the ranks of chemists, metallurgists and electricians. The Electrical Congress offers such an opportunity; and in future it might be worth while to try and arrange general meetings of the American Electrochemical Society simultaneously, and at the same place, with one of its sister societies, the American Chemical Society, the American Institute of Mining Engineers, and the American Institute of Electrical Engineers.

The professional programme of the Washington meeting was suggestive in this respect. While all the papers were electrochemical in character, at least in some respect, yet the majority of them would have appealed to a much larger field than merely electrochemists. Every electrical engineer should read with interest the papers of Profs. Carhart and Hulett, Dr. Wolff, Dr. Weedon and Mr. Zimmerman. Messrs. Carhart and Hulett on one side, and Dr. Wolff on the other side, worked out, independently of one another, a method of producing pure mercurous sulphate by electrolysis, for use in standard cells. The accuracy obtained in the tests is astonishing, and is far greater than has ever been reached before. There seems little doubt that the Weston cell will become the general working standard of e. m. f. Dr. Weedon's paper is suggestive as to the intimate relation which exists between the problems of the lighting engineer and those of the electrochemist. Dr. Weedon's paper gives a large amount of very interesting information on various details of the mechanism of flame arcs, but on the other hand, it also emphasizes how little we still know on electric discharges through gases in comparison with our knowledge of the conduction of the current through an electrolyte. We have for gases no such general law as Faraday's law in electrolytes. Dr. Weedon's results are conclusive in this respect. Of course, we have the electron theory, but it is still in the first stage of its development, although it fairly promises to bring finally all electrical engineering and all chemistry into the realm of electrochemistry. Mr. Zimmerman's results with the aluminium electrolytic condenser appear to show that this apparatus could be used to advantage—perhaps not for purposes of measurements requiring a high accuracy—yet for various general purposes of alternating-current engineering.

Some of the most interesting technical papers which were presented related to metallurgy, which is apparently one of the most promising fields at present for electrochemical endeavor. Electrolytic methods have been chiefly successful in the refining of metals, and from the important paper of Prof. Burgess and Mr. Hambuechen we see that iron is to be added to the list of metals which can be refined electrolytically at a cost that is not prohibitive; the main problem is now to find commercial uses for pure iron. Mr. Veddeks' paper on the economic balance in copper refining emphasizes that electrolytic refining of copper—one of the simplest electrochemical problems in the laboratory—becomes an enormously complicated problem from the financial point of view if worked on a large scale. The great number of variables on which the results depend, explains why the details of operation, like current density, etc., must change from one refinery to the other, if the financial efficiency shall be a maximum. Mr. Johnson's paper on the reduction temperature of zinc oxide was an interesting example of the applications of laboratory methods of measurements to a problem of technical metallurgy; there can be no doubt that work of this kind, carefully carried out in the research laboratories of our large metallurgical plants, will indirectly bring about important advances in the operation of metallurgical processes. Mr. Sjöstedt's interesting paper was an account of a special phase of the electrometallurgical work which has been going on in the past years at Sault Ste. Marie.

The other papers presented at the meeting either referred to electrochemical theory or experimental work. Mr. Mott gave the results of his valuable experimental determinations of the single potentials of the halogen elements; while it is questionable whether his values really represent "absolute potentials," yet this is of small account, since in practice we always have to do with differences of potentials, and any constant additive term which might be added to Mr. Mott's values would drop out of the difference. Dr. Adams—the "father of nickel plating"—and Mr. MacNutt described some observations made in the use of the copper voltameter. Mr. C. F. Carrier's paper was a contribution to the increasing literature on the electrolytic preparation of white lead, while Mr. Davis described some peculiar observations on osmotic pressure and alternating currents which should invite further investigation. Dr. Richards gave a generalization of Thomson's rule, so as to apply to the case that several electrochemical reactions are simultaneously going on; like Thomson's rule, it is purposely based on the simplifying assumption that chemical and electrical energy are the only forms of energy to be taken into account, so that a term of correction due to the role that heat plays in electrochemical phenomena should be applied. But as Thomson's rule is found useful in general practice, Dr. Richards' method of calculation may be considered to be correct to the same extent. In a paper on molecular conductivity, Mr. Reed made a vehement attack upon the dissociation theory, while Dr. Parsons' paper was an able defense of the same theory against criticisms based on the energy principle. Quite a number of the papers had been printed in advance, but it would be well in future to send out advance copies of the papers to all members, several days before a meeting, since this would enhance the value of the discussions.

Dr. Richards' presidential address was an inspiring review of the continuous advance of electrochemistry, full of suggestions as to future developments. With this able address, Dr. Richards retired from the office as president, having been privileged for two years to lead the society to successes far beyond the first fondest hopes of those who conceived its formation. Together with him, Mr. C. J. Reed, the first secretary, retired from his old office, in which he had served the society with

such unselfish devotion and untiring energy. What its first president and secretary have done for the society and thus, indirectly, for the interests of electrochemistry in the United States, will never be forgotten.

THE CHEMICAL ENGINEER.

In this issue we give an extended report of a very suggestive paper by Mr. Herreshoff on the training of the chemical engineer, and of the very animated discussion which followed this paper. The subject is of the highest importance, since the proper training of the young men of to-day will determine not only their own future, but that of the chemical industries of this country. The subject was exhaustively discussed from all points of view, and the differences of opinion were mainly as to the methods of training. With respect to the fundamental point there appeared to be unanimity of opinion; that is, that what is badly needed for our chemical industries are men who are not chemists pure and simple, but who have a good knowledge of physics and mathematics, and a thorough training in engineering. We may add that the rapid advances which have been made in electrochemical industries in recent years were accomplished by just such men, and would have been impossible otherwise.

THE EDISON NICKEL-IRON BATTERY.

On April 28 Mr. Robert A. Fliess, the superintendent of the testing department of the Edison Storage Battery Co., delivered a lecture before the New York Electrical Society on the development of the nickel-iron storage cell. It was especially interesting, for the reason that, since Dr. Kennelly's paper of three years ago, in which this latest invention of Mr. Edison was first announced, Mr. Fliess' statements represented the first authoritative information given out by the manufacturers themselves on this much-discussed battery. With the aid of a great many lantern slides, Mr. Fliess showed the mechanical development of the battery from the beginning up to its present form, and showed curves representing the advances made during this development. For instance, discharge curves were given, showing the ampere-hours obtained per gram of active nickel material and per gram of active iron material. These curves showed that the ampere-hour efficiency of the active material had been doubled since the beginning of the experiments. Mr. Fliess also gave the characteristic curves of the three types, C, D, E, of commercial cells, so far made; type C has certain advantages over D, while D has other advantages over C, and in E the advantages of the two former types are combined. In the latest type the watt-hour capacity, which was given by Dr. Kennelly in his paper, and which had been derived from experiments on somewhat like a test-tube scale, has exactly been reached again for commercial cells, namely, about 14 watt-hours per pound.

While Mr. Fliess thus gave very interesting data on the results accomplished by the gradual improvement of the cell, he did not state the methods by which these improvements had been accomplished. Concerning the relative advantages of the three types, C, D, E, it appeared as though in one of the two former types there was too much nickel and not enough iron, in the other too much iron and not enough nickel, while in the latest type the two active materials are exactly balanced. Concerning the enormous advances made in the utilization of the active materials, the question would be whether they were due to improved chemical or mechanical methods, or to both. Chemical purity is of the greatest importance to insure long life, and this depends on the absolute insolubility of the active materials in the electrolyte. On the other hand, the methods of packing the active materials in the little boxes more or less tightly and of mixing with some conducting material (like graphite) will evidently have a very great influence on the degree to which the active material is utilized. Mr. Fliess laid great stress on those points in which the nickel-iron cell appears to be superior to the lead cell—its light weight, its capability of being discharged at very high rates without losing capacity, its "fool-proofness," and its long life.

The discussion which followed may well be summed up in the remark of Mr. Blizard: "I see the lead cell is in the hands of its friends." The criticisms brought forward by various speakers were mainly that the nickel-iron cell is more bulky and more expensive than the lead cell; and Mr. Bijur asked a pertinent question when he requested to give an exact figure for the number of charges and discharges which an Edison cell will stand. It is, perhaps, still too early to give such a figure, since Mr. Fliess simply replied that, like wine, the Edison cell appears to improve with age. After all that has been said in the case of the Edison cell versus the lead cell, one may conclude that the day is far off, if it ever comes, when the alkaline accumulator will replace the lead cell for general work, but it is equally certain that the Edison battery has very great possibilities for future developments, and that it will surely have a large field of usefulness in special fields, in which the distinct advantages which it possesses are of importance.

THE COMBINATION OF A SOLVENT WITH THE IONS

In this issue we publish an abstract of a paper by Messrs. J. L. R. Morgan and C. W. Kanolt, which is very interesting since, by a method somewhat similar to Hittorf's determination of the transport numbers, the authors show conclusively that in certain solutions a combination of the solvent with the ions exists. By applying this result to a simple aqueous solution of a salt they also show that the discrepancies found between the electrolytic dissociation theory and the facts can be made to disappear. This is perfectly correct. It may be argued, however, that the results of the authors cannot be directly applied to the case of a simple solution of a salt in a solvent, since what they experimented with were rather solutions of a solution in another solvent. Nevertheless, the facts ascertained by the authors are very interesting. On the other hand, it would be extremely valuable to work out a method for determining decisively what the ions are in a simple solution. For instance, in a dilute aqueous solution of sodium chloride we assume the ions to be sodium and chlorine, but there exists no evidence which would prove that, for instance, combinations of the sodium or chlorine ions with water do not exist in the solution. What is mostly needed in this respect is experimental evidence, not theoretical speculation, and we trust such experimental evidence will soon be brought forward.

FARADAY SOCIETY MEETINGS.

An ordinary meeting of the Faraday Society was held on March 21 at the Institution of Electrical Engineers, London, Dr. O. J. Steinhart in the chair.

A paper by Dr. F M. Perkin and Mr. W. C. Prebble on the "Electrolytic Analysis of Gold" was read in abstract by Dr. Perkin. An abstract of this paper was already published in our April issue on page 159.

Thin-Film Electrolysis.

Mr. Charles R. Darling then read a paper on "Thin-Film Electrolysis, and a Proposed Application to Printing," which was illustrated by experiments. While investigating a process for letter press printing by electrolysis without the use of ink—an extension of Bain's well-known telegraphic printing—the author found that the final results of electrolysis, when the electrolyte forms only a thin film—often differ materially from those observed in an ordinary cell. In these experiments a carbon or metal plate (it was immaterial which), formed the anode; on this was placed an impression pad, consisting of some sheets of moist blotting-paper; upon this was the trial sheet, carrying the electrolyte film, and on this the cathode type or coin.

Voltages from 6 to 200 were employed. To obtain a clear image of the type a certain minimum strength of solution is requisite. The first experiments were made with saline solutions; silver nitrate gave a clear, permanent black image of the type, but the paper, of course, darkens on exposure; copper sulphate and nitrate yielded images that faded after a time; the same unexpected result occurred with lead, mercury salts, and bismuth. The best images were obtained with manganese salts. These consisting, as they did, of the oxides or hydrates, were quite permanent; all purely metallic deposits, excepting silver, disappeared after a time. In the case of non-saline solutions the paper, which might consist of asbestos or pure Swedish filter-paper, soaked in distilled water, acquired the properties of an exposed photographic plate, and on treating with a silver salt and developer a perfect image of the cathode was obtained, even after a long interval. The latent images are not due to hydrogen peroxide, nor to metallic compounds, as they occur with carbon electrodes; but they reside in the surface of the paper in contact with or towards the cathode. The author ascribed them to a class of phenomena that have been investigated by Bose and termed "the response of inert matter to electrical stimuli," and thinks they are probably the result of some state of strain set up in the film by the current. As regards the fading of the metallic images, this may be simply due to recombination, although that explanation is not entirely satisfactory.

In the discussion which followed, Dr. H. Borns asked whether the author had treated his latent images with any solutions before developing. Mr. N. J. Blumen said that in some electrolytic printing that he had carried out they had used some organic solutions with good results. Mr. Fontana suggested that the latent images might be due to occluded hydrogen. Dr. Perkin thought this supposition could be tested by exposing the paper to an oxidizing agent. Mr. Bawtree asked whether it were possible to get rid of the latent images. If so, some light would be thrown on their cause. Mr. Prideaux asked whether the author had tried developing anode images where carbon formed the anode, so that no metal went into solution. Dr. Steinhart did not agree with the "strain" theory put forward by the author. All materials contain some trace of saline matter, and one is almost sure to get chlorine or some such substance given off on electrolysis. Mr. Darling, in reply to Mr. Bluman's remarks, said that organic substances eventually discolored the paper. He did not think hydrogen the cause of the latent images; certainly hydrogen peroxide does not destroy the image.

The ordinary April meeting of the Faraday Society was held on Wednesday, April 13, Mr. James Swinburne in the chair.

Alloys of Copper and Arsenic.

Mr. Arthur J. Hiorns read an abstract of his paper on "Alloys of Copper and Arsenic." The object of his investigations was to ascertain the exact relation between copper and arsenic in binary alloys, and the limit of proportion of arsenic that can be retained in copper in the cold solid state.

The addition of arsenic lowers the melting-point of copper uniformly down to about 14 per cent, when a steep fall in the freezing-point curve occurs, reaching its lowest point at 685° C. This alloy contains 19.2 per cent of arsenic, which corresponds to the formula Cu_5As. The alloy, with 22 per cent of arsenic freezes at 708°, and the freezing point gradually rises until the alloy with 28.34 per cent is reached at 747°; this is Cu_3As. At 810°, Cu_5As_2 freezes, containing 32.2 per cent of arsenic. Beyond this point the freezing point gradually falls again, until a minimum is reached at the alloy with about 35 per cent of arsenic. The curve then rises to another summit at 740°, corresponding to Cu_2As, with 37.24 per cent of arsenic. From this position the curve decends to 702°, with the alloy containing 41 per cent of arsenic; this is nearly the practical limit of the direct combination of copper and arsenic.

The top surfaces of many of the alloys were photographed. The types of pattern visible on the etched surface depend upon the position of the freezing point on the curve. For alloys whose freezing point is on or near the summit of a curve, the whole of the section is composed of one substance, generally made up of crystal grains having fine boundaries. When, by addition of copper or arsenic a summit of a curve is left, the lines between the crystal grains widen and become filled with a network of matter differing from that of the crystals and generally showing a more or less striated appearance, so characteristic of eutectics. As the bottom of a curve leading from a summit is reached the eutectic occupies the whole surface. It is noticeable that the alloy of minimum fusion of copper-arsenic alloys has an extremely fine striated structure. Any deviation in composition from the eutectic proportion causes the breaking up of this striated pattern, and grains of one of the constituents appear in the eutectic matrix.

A microscopic examination was also made of polished sections of the various alloys. These, when viewed in daylight, are all copper-colored in those with little arsenic, and gradually get paler as the arsenic is increased. When the alloy with 19.2 per cent is reached, the surface appears of a pale blue color, and this is continued up to Cu_5As, containing 28.34 per cent, which is of a deeper blue color. The alloys between 19.2 and 28.3 per cent have a paler blue tint, because the blue constituent is associated with a constituent richer in copper, forming a eutectic mixture. The alloy with 30.0 per cent is of a light purple color, and when Cu_5As_2 is reached, containing 32.2 per cent, a full reddish purple is obtained. This purple color maintains up to the limit of these experiments with 45 per cent of arsenic, but gets gradually paler. The paper was concluded by a detailed description of the various alloys fully illustrated by excellent photomicrographs.

Mr. E. G. P. Bousfield then read two papers on "Experiments with a New Primary Cell," and on the "Determination of the Percentage of Ozone in Gases." Both papers are abstracted in the Synopsis of our present issue. In the discussion of the paper on the Bousfield primary battery, Mr. W. R. Cooper referred to the disadvantages of both nitric acid and caustic soda as electrolytes; the high e. m. f. of the cell was only apparent, because it rapidly fell to a working value of 1.8 or 1.9; he would like to have seen comparative tests made, say with a bichromate cell. Mr. J. Swinburne mentioned a suggestion made by Dr. Swan, that the cell would be improved if it were converted into a three-fluid cell, with a neutral electrolyte (e. g. $NaNO_3$) in the mid compartment.

Edison Storage Battery.—Mr. R. A. Fliess recently delivered an interesting address on this battery before the New York Electrical Society. We comment on it in an editorial.

THE CHEMICAL ENGINEER.

The very important and timely subject of the training of the chemical engineer was discussed in a most interesting manner by Mr. J. B. F. HERRESHOFF, in a paper recently read before the New York Section of the American Chemical Society. This paper elicited an animated and prolonged discussion in which industrial chemists and university professors equally participated. In the following we give an abstract of the paper and the discussion. The complete paper and discussion may be found in *Science*, April 8.

Mr. Herreshoff pointed out that in 1850 the value of manufactured products in the United States was $1,000,000,000, and in 1900 it was $13,000,000,000 (while the value of unmanufactured agricultural products was estimated at $4,000,000,000). In bringing about this enormous increase, chemistry, assisted by engineering, has played a most important part. Our iron and steel industries, our whole field of metallurgy, and, indeed, the majority of the great industries would have remained in a crude, dormant state, had it not been for the important work of the chemist and his more practical brother, the technical chemist. While it is true that the number of chemists engaged in active work in this country has increased in the last thirty years in a proportion far beyond that of the increase in the value of manufactured products, yet we are still backward in the employment of chemists when we compare our position with that of Germany. Concerning this point Mr. Herreshoff gave some interesting data.

In this country there are numerous examples where the technical chemists have immensely improved manufacturing conditions, either by lowering costs or by producing a higher quality of product. There is still much room for improvement, and Mr. Herreshoff expressed the opinion that there is hardly a plant in the country turning out products requiring chemical skill where marked improvements could not be made by the very best work of technical chemists in effecting changes that would reduce the cost of labor and fuel, in recoveries from waste products or by producing better material.

During his long experience in connection with chemical manufacturing and metallurgical work, Mr. Herreshoff has found that the majority of chemists who are employed as analysts, technical chemists and as works or department managers, have perfected themselves in chemistry alone, and seem to have neglected the importance of physics and engineering. If a chemist wishes to achieve the greatest success in industrial work he should not undertake the problem at all, unless he has made up his mind to perfect his mathematics and become thoroughly familiar with physics as well as mechanical engineering. It seems a great mistake that the term technical chemist has been used in connection with chemists who are obliged to apply chemistry in manufacturing processes. We should speak rather of chemical engineers, as we speak of metallurgical engineers, mining engineers, electrical engineers.

present. Our colleges should consider this matter more seriously than ever, and do their best to make the course in chemical engineering as complete and perfect, in every way, as possible. Chemical engineering necessitates a greater variety of engineering than all the other branches of engineering combined. In designing the apparatus that is employed in conducting the endless variety of chemical and metallurgical processes, every known metal and alloy is used in every conceivable variety or form. All kinds of brick are used, acid, basic, neutral and vitreous, glass, all sorts of pottery-ware, porcelain, stone, rubber, coke, asphalt, wood, cements, etc., and these in every combination and form which the best chemical engineering skill can devise to improve old methods and properly conduct new processes. In order to select the best material with which to carry on difficult prob-

When noticing the enormous field of manufacturing in this country, one cannot help feeling that a study of mechanical engineering should be very much more general than at lems, the chemical engineer must have a wide knowledge of the action of acids, alkalies and chemicals under all conditions of solution and heat, upon all known substances which could be employed to carry on the processes. Generally in new problems, carefully conducted investigations have to be made on a small scale, to show conclusively the best substances to be used.

In the designing and construction of plants and apparatus, the chemical engineer has not only to select the most suitable material, but he must so carefully study the function of every detail of the apparatus to be used, that each part will successfully meet the full requirements. Each and every part must be proportioned to what it has to do; everything must be proportionately strong and large enough for the purpose, always avoiding unnecessary extremes in order to curtail the first cost of the plant. The desired end must be met in the simplest possible manner, and the devices so arranged that while operating they will be so nearly automatic that good results will be achieved with the least possible labor. The plants must be so designed that the greatest yields will be obtained and the finest products turned out.

But after all this is done the chemical engineer will not be thoroughly skillful and up to date unless he designs every part of the apparatus so that it will last the longest possible time. Everything must be arranged so that when repairs are required they can be conducted with the least expense.

For the successful operating, maintaining and improving the condition of plants where chemical skill is employed, the manager or superintendent and his assistants must be trained not merely in chemistry, but in mechanical engineering as well. Training in business and departmental management is also highly desirable. However perfectly a plant and its apparatus may be designed and erected, it will not necessarily give successful results unless every machine, furnace, still, condenser, tower, etc., is operated under the management of a man who is fully conversant with the function of every detail of the apparatus. If the superintendent is properly educated in chemical engineering and has had a proper training as an assistant superintendent or practical investigator, and especially if he has a natural fondness for machinery and mechanics, then success will crown all his work. Whenever there is a difficulty—something breaks down and bad results follow—then he will at once clearly define the reason for the trouble and take the proper steps in completely correcting the evil. He gives true reasons for everything that is done in the various departments of the plant. He sees much going on that is unreasonable, and step by step he brings the unsatisfactory work up to a higher and higher standard. His assistants are chemical engineers, and he inspires great confidence and interest in them by a course of training that causes them to think and reason from every standpoint, so that before taking action, everything having an important bearing on the chemical, physical, engineering, business and labor sides of the problem in hand is most carefully considered.

The chemists in the analytical laboratory are not always college graduates, as most of the work is of a routine nature, requiring great skill in manipulation, but not necessarily an extensive knowledge of chemistry. These men when confined to this work have no opportunity to employ engineering skill except in perfecting the apparatus used in making chemical analysis. It is of the utmost importance that their analyses are accurate and quickly performed. It is the custom in all well managed industrial laboratories to investigate frequently the analytical methods used. For this reason the most desirable analytical methods are often found in industrial laboratories and the colleges should endeavor to keep abreast with the best practice operated there. There is no reason why the training of analysts in large laboratories should not be of the highest order.

The future success of any well-established industrial institution of a chemical nature is in grave peril if it does not have

an investigation or research department. The manager of this department must be by education a chemical engineer. He should have had large experience as a practical business manager of plants, and a direct acquaintance in the designing, reconstruction and repairs of the same. This department must have a properly equipped research laboratory. The head of this research laboratory must be possessed of very high attainments as a chemist and physicist, with a fair knowledge of mechanical engineering.

The great majority of chemists in this country are engaged in practical work where they need engineering assistance, and in such cases the chemist who is not an engineer would have to consult the engineer for practical advice, and the engineer seeks chemical assistance from the chemist, and, without a knowledge of chemistry, obtains but little satisfaction. A complete understanding of the various problems must come from a brain that can think in both chemistry and engineering. The dignity and fame of chemistry will not be injured by joining in close union with engineering. Indeed, the real value and glory of chemistry comes from its application to useful products that add comfort and happiness to the human race. These applications cannot be carried on without the aid of engineering. Applied chemistry would be greatly benefited in this country if the colleges would come in closer touch with the manufacturer.

In the discussion Dr. T. J. Parker (General Chemical Co.) remarked that if the application of chemistry to manufacturing processes is desired, it is certainly necessary for the young chemical engineer to have a knowledge of mechanics or engineering as well as chemistry, in order to apply it efficiently in our factories. The opening for the industrial chemist in the next five or ten years seems simply phenomenal.

Mr. M. C. Whitaker (Welsbach Light Co.) remarked that when the processes connected with manufacturing industries are referred to the chemist for improvement, he repairs to his laboratory and goes through some very serious painstaking work. But this work is not appreciated by the superintendent because he is not a chemist. What the superintendent asks for is actual merchantable results. The chemist is generally not a man who is capable of transmitting from a laboratory to a factory the ideas which he has developed. To change this situation, he should have a knowledge of electrical and mechanical engineering, and he should have that knowledge of getting along with people so that after he has prepared his plans and laid them out, he can get help to bring about those results which he desires. He must not only develop new ideas, but he must have the knowledge to put them into practice. Such men, instead of being assistants in our manufacturing industries, will be leaders.

Dr. William McMurtrie agreed with the opinions expressed, but emphasized that the training of the technical chemist, as well as that of every technical and professional man, should begin much earlier than the entrance to the technical school. It should begin even in the earlier grades of the primary school. Here the idea should be abandoned that the young minds are too immature for study and systematic work, that the children need to be amused rather than seriously educated; that they must be trained by kindergarten methods in lines which later must be traversed again in the serious struggle for education. Thus precious time is lost at the age when the mind is most pliable and receptive. It would be far better to return to the old-fashion methods of the three R's—reading, writing and arithmetic.

Prof. Edward Hart (Lafayette College, Easton, Pa.) thought that we must in the first place reconcile ourselves to the idea of doing the best we can in four years. It is necessary to first teach the science of chemistry thoroughly and well, so far it is possible, and then to teach engineering, because the chemical manufacturer is an artisan. He must be an artisan to a certain extent. In the four years course it will not be possible to get into a man more than the elements of engineering, but if this is done well the product will be quite different from that turned out at the present time.

Prof. W. A. Noyes (Rose Polytechnic Institute, Terre Haute, Ind.) emphasized that the basis of the training for the technical chemist and for the chemist of all kinds must be a thorough training in analytical chemistry. This training has now become inferior to what it was a few years ago. Industrial chemistry can be put into a four years course only to a comparatively small extent. It is manifestly impossible to train every young man for that particular field into which he will later go.

Prof. C. F. Chandler (Columbia University) said that the difficulty is that our students, entering a college for four years, never know what particular branch of chemistry they intend to pursue in after-life. They are, therefore, treated all substantially alike, and get all substantially the same chemical education. But our young students apparently expect the instructors to do their work. "When I was a student I went into Wöhler's laboratory. He gave us a lecture every morning, and we were expected to attend that lecture and make the most of it. Then we went into the laboratory. He handed me a piece of triphyline, and said: 'I want you to get some lithia out of that.' He did not give me an hour's lecture and tell me how to make lithia and have me write it down. He gave me a piece of the mineral, and I had to hustle and find the solution of the problem myself. He said: 'You have to make some lithia out of that, and after you have made up your mind, come to me and I will look over your proposition and see whether it is right.' That was the way chemistry was taught in Wöhler's laboratory. There was a small number of students, and that method of instruction was carried out." Now students expect that they are told every step which they have to make in an analysis. The speaker did not think that instruction in engineering can be given in a four year's chemical course, although it would be highly desirable.

Prof. A. A. Noyes (Massachusetts Institute, Boston) thought that institutions could do a great deal of good by laying out a definite course of fifth-year work, leading to some higher degree. There is a difference between a chemical engineer and an engineering chemist. What is wanted of a factory chemist in this country is rather the power of solving new problems and of making improvements in processes—a power to be acquired far more by a good chemical training, which should include a large proportion of research and other work, requiring independent thinking, than by engineering training. If instruction in mechanical engineering is to be given in chemical courses, either the time devoted to analytical chemistry or to modern languages must be reduced.

Prof. H. P. Talbot (Massachusetts Institute, Boston) thought that analytical chemistry is some times taught in a too abstract way, while it is possible to connect analytical chemistry in the mind of the student more closely with the scientific or industrial problems to which it is to be applied, and in this way stimulate his interests and develop his ingenuity.

Dr. Wm. Jay Schieffelin pointed out that most of the industrial processes are elaborations or applications of methods used in analysis; therefore, the technical chemist should know the methods. It is very hard to-day to get a man who is a good analyst, upon whose analysis one can entirely rely. If he must make an analysis which he has not made before, he takes a book of selected methods and goes through it, but his results are not satisfactory. The speaker thought that knowledge of the German language is immensely important, because the German works, Beilstein and Dammer, are to-day the chemists' bibles, and contain nearly everything on organic and inorganic chemistry which he wants to learn about, and we haven't their parallel in the English language.

Dr. Hugo Schweitzer expressed himself absolutely against

the introduction of chemical engineering in the education of chemists, and wants to restrict the same to pure chemistry. It is the manufacturer who asks that we should be both chemists and chemical engineers. The speaker thought that it is the employers who need education. What they now do is to engage a chemist, to pay him a generous salary and to think he ought to be a chemical engineer besides. What the manufacturers ought to do is: they should take the graduates from the university as they are educated in pure chemistry and educate them at their works at their expense during one or perhaps two years to become technical chemists and chemical engineers.

Mr. MAXIMILIAN TOCH suggested that the colleges invite men to lecture who have been successful in manufacturing industries, and who naturally can impart knowledge to students such as a professor is not expected to have. The college laboratory is totally different from a factory.

Prof. M. T. BOGERT (Columbia University) thought that the manufacturer really wants two kinds of chemists. First, what may be called technical directors, men who are trained more thoroughly on the mechanical side than on the chemical side, who understand the handling of both men and machinery, and who know in a general way the chemical processes to be carried out; and, secondly, scientifically educated chemists. The training of these two classes of chemists should be quite different. The man who is working in the laboratory, the man behind the gun, is the man who has accomplished results in Germany as well as in this country. Progress in Germany in technical chemistry has been due largely to the work in research laboratories by men who had no engineering training, and the speaker emphasized that it is only through the establishment of such research laboratories that the American chemist can hope to compete with the German chemist.

Mr. W. H. NICHOLS (President General Chemical Co.) said that the young man who goes to college to get his technical training should determine whether he is going to use it in the realm of pure research or whether he is going to be a chemical engineer. A college course is simply a foundation on which the further education is to be built in after life.

WASHINGTON MEETING OF THE AMERICAN ELECTROCHEMICAL SOCIETY.

The fifth general meeting of the American Electrochemical Society was held in Washington from April 7 to 9, and the professional proceedings as well as the social features of the convention were again an unqualified success, although the attendance was smaller than had been expected. The members and guests who registered numbered somewhat less than 100, an alphabetical list being given at the end of this report.

The lecture hall of the Columbian University had been placed at the disposal of the Society, and there three morning sessions were held, devoted to the reading and discussion of papers, while in a special evening session on April 7 the retiring president, Prof. J. W. Richards, delivered his address on the continuous advance of electrochemistry.

The first meeting was opened by a speech of hearty welcome by President C. W. Needham, of the Columbian University, who remarked that Washington is a sort of switchboard where one can make connection with every part of the country, and even of the world. He spoke of electrochemistry as being now in the front rank of the sciences and arts, and of its influence in saving labor and making life more worth living. President Richards thanked him for his inspiring words and for the hospitality extended. The secretary, Mr. C. J. Reed, then presented his annual report, in which he gave a statement of the membership and of the publication and distribution of the Transactions. During the last year 196 new members were elected, and the total membership is now somewhat near 700. The treasurer, Mr. P. G. Salom, could not attend the meeting on account of death in his family, and his report was read by Mr. Reed. It shows that the profit of the Society from the time of its first existence up to now amounts to $1,652.52. In addition the Society holds $250 for the Frenzel prize, which was offered for the best paper on the subject of rare metals. The president announced that this prize has not yet been competed for, and the offer is still open. Mr. Carl Hering moved that in future the secretary's and treasurer's reports should be printed in advance. This motion was carried. An amendment to the constitution was unanimously carried, according to which the president, vice-presidents and managers shall, after the expiration of the full term of office to which they were elected, be ineligible for immediate re-election.

The president announced that the board of directors has decided to hold the next general meeting during the week of the International Electrical Congress in St. Louis in September. Three official delegates of the Society to the Congress will be appointed by the board of directors. They will present special papers before the joint meeting of the Electrochemical Section of the Congress and the Electrochemical Society.

The result of the election of officers for the coming year was announced by the tellers during the session of Saturday. As evidence of the interest taken by the members in the Society it may be mentioned that 361 legal votes had been cast; that is somewhat more than 50 per cent of the total membership. Prof. Henry S. Carhart was elected president, Messrs C. J. Reed, E. G. Acheson and C. P. Burgess vice-presidents, Messrs. W. H. Walker, C. E. Acker and E. Weston managers. Mr. S. S. Sadtler was elected secretary, and Mr. G. P. Salom was re-elected treasurer. Prof. Burgess had been elected both for the offices of vice-president and manager, and accepted the former office.

The social features of the meeting were extremely enjoyable, and much credit is due to the untiring efforts of the local committees, with Col. Samuel Reber as chairman and Mr. Clinton Paul Townsend as secretary of the general committee, and Dr. N. M. Hopkins as the chairman of the entertaining committee, who, with the other Washington members of the Society, successfully endeavored to make everybody feel at home. The Cosmos Club, through its board of managers, extended the courtesies of the club to members of the Society, and Mr. E. J. Prindle courteously placed a room of his law office, including the services of a stenographer, at the disposal of the members of the Society.

On Thursday noon, the members of the Society were presented to President Roosevelt at the White House, to shake hands with the chief magistrate of our country. On the afternoon of the same day a complimentary excursion on a special "Seeing Washington" car to all parts of the city was greatly enjoyed, while attention was called by means of a megaphone to everything that could possibly be of interest. Since the weather was good and the parks of Washington appeared in the first green of the spring, this trip was greatly enjoyed.

On the afternoon of Thursday a visit was made to the Navy Yard, where the visitors had an opportunity to see the shrinking of a jacket tube of one of the largest modern guns. On the afternoon of Saturday visits were made by different

parties to the Bureau of Chemistry, the Bureau of Engraving and Printing, and an excursion, either by trolley or boat, to Mt. Vernon. The National Bureau of Standards was open for inspection on all days of the meeting.

On the evening of Thursday, immediately after Prof. Richards' presidential address, a complimentary smoker at Rauscher's was greatly enjoyed, a special feature of which was the drawing of cartoons with lightning rapidity by Mr. Clifford K. Berryman, of the staff of the *Washington Post*. While almost all his cartoons represented senators, congressmen and politicians of national fame, one was a highly amusing caricature of Dr. Wiley, and we regret that the confiscation of this cartoon by the object of the sketch prevents us from reproducing it here.

On the evening of Friday a subscription banquet was held at the Shoreham. Dr. Wiley was a most successful and humorous toastmaster. His first toast was to the President of the United States. He remarked that after-dinner speeches should always begin with a toast to the President, "we are now a nation 14,000 miles wide, 7000 long and weigh twenty-five billion trillion pounds." He then spoke of the wanderings of the Chinamen from the East, across Behring Strait, down to his paradise in Pennsylvania, where he founded a river and a beautiful valley by the name of Lee-High. To show that at least something good had come from Bethlehem, Dr. Wiley then introduced the retiring first president of the Society, Prof. J. W. Richards, who gave an historical sketch of the phenomenal rise and activity of the Society.

Dr. Wiley then told a lot of jokes about Ann, to arrive finally at Ann Arbor, and introduce the new president, Prof. Henry S. Carhart, to speak of affinity and alliance, as he came from the University of Michigan, which for years has been wrestling with the question of co-education. Other speakers were the retiring secretary, Mr. C. J. Reed, of Philadelphia; President Charles W. Needham, of Columbian University, and Col. Samuel Reber, of the War College, who asked the banqueters to drink the health of wives and sweethearts.

At the conclusion Dr. Wiley read the following telegrams, all stated to have been received by Prof. N. Munroe Hopkins, and expressing regrets at the inability of the senders to be present. The last one was written on asbestos, and had been transmitted by the "Subterranean and Astral Postal Telegraph Company:"

Goettingen, April 8—Afraid to attend another banquet of the Electrochemical Society. Have struggled for a year to understand Wiley's joke of last year. What did he mean by "A. E. S."? Prepay and cable answer.—W. Nernst.

Llewellyn Park, April 8—Sorry can't be at banquet to-night. Detained finishing storage battery which will drive motor car 500 miles. Car can easily be returned by freight.—T. A. Edison.

Berlin, April 8—Regrets at not being able to be present at banquet to-night. Financial osmotic pressure high, which phases me considerably.—J. H. Van't Hoff.

Styx, April 8—Sorry cannot come to-night. Important business with my large sulphur plant products. How science has grown since my time! I see Graham Bell is also flying kites. Kindness of Charon.—Benjamin Franklin.

In the following we give a concise report of the papers presented at the meeting and the discussions which followed:

Standard Cells.

The first paper was presented by Dr. F. A. Wolff, of the National Bureau of Standards. Since the International Electrical Congress to be held in St. Louis will probably take some action in redefining the fundamental electrical units, the author gave a review of the present situation. The speaker first gave the definitions adopted at the Chicago Congress for the three fundamental units, and remarked that the Chamber of Delegates, in which the leading governments were officially represented, recommended the definitions which they drew up as a basis for international legislative enactment. However, comparatively few of the countries have enacted laws defining the fundamental electrical units; and those countries which have are far from being in accord.

The chief objection which is to be made against the suggestions of the Chicago Congress, is that since the three units are connected by Ohm's law, only two are independent, and the third should be defined in terms of the other two. Moreover, since the Chicago Congress, it has been found that the specifications for the silver voltameter are entirely inadequate; redeterminations of the e. m. f. of the Clark cell gave values nearer to 1.433 than 1.434 volts. Finally the application of the potentiometer method to measurements of current and e. m. f. and the improvements in the method for measuring low resistances have set a standard for accuracy for relative measurements of the fundamental quantities far in excess of that fixed by the reproducibility of the fundamental standards.

Of the three units, ohm, volt and ampere, the specifications for the ohm are almost free from criticism and may be made entirely so by the adoption of slight modifications. The ohm will therefore certainly be one of the two fundamental units to be concretely defined. For the second one, we must therefore take either the ampere defined in terms of the silver voltameter, or the volt, defined in terms of the standard cell. The arguments in favor of the former are mostly based upon the assumption of Faraday's law as a fundamental law of nature; while this may be the case, yet numerical applications of the same are based on the supposition that only the one reaction under consideration is taking place, and that no other reactions are going on simultaneously. But in practice it seems that such other reactions play a not unimportant part where the highest precision is sought. Recent researches of Dr. Karl E. Guthe of the Bureau of Standards seem to indicate, however, that the ampere may be defined in terms of the electrochemical equivalent to an accuracy of possibly one part in 40,000, which is considerably greater than the accuracy with which, up to this time, the standard cell can be reproduced.

There are, on the other hand, a number of practical objections to the choice of this method of defining the second fundamental unit. With a given silver voltameter, only currents lying within certain narrow limits can be accurately measured. The duration of the measurement must be great enough to get sufficient silver deposit for exact weighing, and to permit the time to be measured with sufficient accuracy. Tedious double weighings must be made to determine the amount of silver deposited. The result finally obtained gives the average value of the current employed, and cannot be utilized for the accurate measurements of other currents, except by reference of the result to a standard cell, and standard resistance, or to an electrodynamometer, in which case the accuracy is not as great as by a direct reference to the standard cell, even in its present state of reproducibility.

The points in favor of the choice of the volt as the second fundamental unit, and its definition in terms of the standard cell were then summarized by Dr. Wolff as follows. Any voltage may be directly measured without any difficulty in terms of the standard cell by means of the potentiometer with an accuracy practically limited only by the accuracy of its calibration and the reproducibility of the cell. The accuracy with which the standard cell can be reproduced, has for some years exceeded all practical requirements and is still open to greater accuracy by specifying more precisely the manner of purification and preparation of the materials employed. The resulting definition of the ampere in terms of the ohm and volt corresponds to the actual method employed in precision measurements of current intensity by the potentiometer method. Only a few moments are required for a measurement and the method is applicable to the measurement of currents of any magnitude, the practical limit being fixed by the carrying capacity of the resistance standard through which the current is sent. The accuracy is limited only by the errors of calibration of the apparatus employed

The Clark and Weston cells are the only ones which are to be considered. Investigations thus far recorded indicate that differences between individual cells of either type, set up from materials obtained from various sources, agree with each other to within 0.0002 volt, corresponding to a slight advantage in favor of the Clark cell on account of its higher e. m. f. The standard of cells of either type is equally satisfactory.

While both the Clark and Weston cells have thus the essential qualities for standard cells, yet the Weston cell has the following important practical advantages. The high temperature coefficient of the Clark is a serious obstacle to measurements of the highest precision, while that of the Weston cell is at ordinary temperature less than one-twentieth as large, so that errors due to temperature uncertainties are correspondingly reduced. Another source of error in Clark cells is that due to hysteresis attending temperature variations which in cells a number of years old may be very considerable. In the Weston cell the equilibrium is more rapidly established, and the error can never be as large. The average life of Clark cells is quite short, owing to the tendency of the cell to crack at the point where the platinum terminal is fused in at the amalgam limb; this may be obviated by a modification in construction, but not without introducing complications. In Clark cells a layer of gas is formed at the amalgam surface, even when carefully neutralized solutions are employed. This would interrupt the circuit, thus rendering the cell useless. In the Weston cell no gas is formed. For these reasons the author is certain that the Weston cell will displace the Clark cell.

PHOTOGRAPH TAKEN AFTER THE FRIDAY SESSION

The author then took up the important question of standard methods of purification or preparation of the materials employed in standard cells. He gave rules for the preparation of pure zinc, cadmium, zinc sulphate, cadmium sulphate, and finally mercurous sulphate. The last one is of the greatest importance, since the experience of former observers has shown that the main source of variation in the e.m.f. of standard cells is due to the mercurous sulphate.

The relatively slight changes in the e. m. f. of Clark and Weston cells, produced by small inverse currents, seem to indicate that mercurous sulphate is formed at mercury electrode under these conditions. An experiment was accordingly made to test this. It was found that with neutral solutions a basic salt containing also mercuric compounds was formed at the mercury anode, while with an acidified solution a beautiful crystalline product was obtained. When the solution is stirred, larger current densities may be employed, and in addition there is less tendency for the formation for basic salts due to the accumulation of the product over the surface of the mercury. A most satisfactory product is obtained by the use of a 5 per cent sulphuric acid solution and a current density of 0.1 ampere per square decimeter. With higher current densities there is a tendency for the mercury surface to oxidize and tarnish, and there is danger of the formation of mercuric sulphate.

The apparatus employed by Dr. Wolff and exhibited at the meeting consists of an outer crystalline dish containing a second crystalline dish, of smaller diameter and height, in which is placed a shallow plate having a diameter one or two centimeters less. On the latter is placed pure double distilled mercury which forms the anode, and in the space between the two crystallizing dishes is introduced a layer of mercury forming the cathode. Five per cent sulphuric acid is then introduced to a depth such that the inner dish is submerged to a number of centimeters. The liquid is stirred by a glass stirrer, driven by a motor, on the shaft of which is also a shield to prevent metal particles from the bearings from falling into the cell. The stirring should be vigorous enough to prevent the whole surface from being covered with the mercurous sulphate formed and to keep the mercury in motion. Connections to the current supply are made by means of glass tubes with platinum terminals fused into one end and filled with mercury. To reduce the loss occasioned by the mechanical carrying of the mercurous sulphate out of the inner dish, the latter is covered with a third crystallizing dish, which is inverted and has a hole in its center to permit the introduction of a stirrer and the anode connection. The product formed collects under the rim of the plate, and may be subsequently collected.

The sulphuric acid solution contains no trace of mercuric salts. The mercurous sulphate itself contains no mercuric salt, and since it is obtained from pure mercury and pure sulphuric acid it is hardly likely to contain any other impurities.

It has been suggested that the size of the grain of the mercurous sulphate may have some influence on the electromotive force of the standard cell, which is quite likely the case when the grains are small, owing to difference in solubility. With the mercurous sulphate produced by the electrolytic method, the crystals are fairly large, as shown by their rapid sedimentation, and there is little likelihood that there will be any difference due to this cause.

The author emphasizes again the very marked superiority of the Weston cadmium cell with saturated solution over the Clark cell which should certainly lead to the entire displacement of the latter. He urges that the saturated Weston cell should be adopted as one of the fundamental standards, if the St. Louis Congress should decide on defining the volt in terms of the standard cell. As a working standard of the e. m. f. the portable cell sold by the Weston Electrical Instrument Co., in which the solution is saturated at 4° C., and which does not contain any excess of cadmium sulphate crystals, can hardly be excelled. A number of such cells have been under constant observation at the Bureau of Standards, and show differences in the course of a year and a half, not exceeding a few parts in 100,000. This constancy, together with a temperature coefficient so small that it may be neglected in all but measurements of extreme precision, makes it fulfill all the essential requirements of a secondary standard. In addition, the use of

such cells simplifies the construction of potentiometers, as no provision has to be made for variations in e. m. f. with temperature, and the potentiometer current can therefore be adjusted by applying the cell to the terminals of a fixed resistance.

Preparation of Materials for Standard Cells and Their Construction.

The next paper on the programme, by Prof. Henry S. Carhart and Dr. George A. Hulett, was presented by Prof. Carhart, who emphasized that in the preparation of standard cells the chemical side of the problem has hitherto received too little attention. The authors first gave standard methods for preparing mercury, cadmium sulphate, cadmium amalgam, and then described a new method which they have developed for making mercurous sulphate by electrolysis. Their method is in all fundamental points identical with that developed independently by Dr. Wolff, although differing in details. The object is to secure Hg_2SO_4 free from nitrate, using only mercury and sulphuric acid, and to secure at the same time a sufficiently rapid reaction without the use of a strong acid. This led them naturally to the electrolytic method which is described as follows:

In a flat-bottomed beaker or deep crystallizing dish is placed mercury a centimeter or so deep. This is covered with dilute sulphuric acid (one to six) to the depth of some 10 centimeters. A platinum wire, protected, except at its end, by a glass tube, makes contact with the mercury, which serves as the anode; the cathode is a piece of sheet platinum in the H_2SO_4 solution. A current of about 0.3 ampere is passed from the mercury into the solution; crystalline mercurous sulphate at once begins to separate on the surface of the mercury. A stirrer, consisting of a glass rod, bent at right angles at the bottom, must be used to keep the mercury surface exposed. The foot of the stirrer passes close to the mercury, and must be driven rapidly by a motor.

HENRY S. CARHART,
President American Electrochemical Society.

About 2.8 gm. an hour can be prepared in this way. The sulphate should be protected from the light. By means of a separate funnel the excess of mercury may be readily removed from below, leaving the sulphate with more or less finely divided mercury mixed with it. The preparation is often somewhat gray on account of the presence of mercury in a state of fine division. This mercury is a distinct advantage, because it insures the absence of the mercuric salt.

The authors recommend this method strongly as a standard preparation of mercurous sulphate. It gives a lower e. m. f. with mercury than any preparation obtained from $HgNO_3$ and H_2SO_4 or a sulphate. Samples made at different times and with different materials show an exceedingly close agreement. The authors add the precaution that the sulphate formed during the first few hours should be rejected unless one is sure of the purity of the mercury. After the electrolysis has proceeded for some time, the solubility of the mercurous sulphate is put in evidence by the appearance of mercury on the platinum cathode.

While Dr. Wolff had established the chemical purity and uniformity of the electrolytically prepared mercurous sulphate, Messrs. Carhart and Hulett have gone further, and have actually employed it in Weston cells. They give the following rules for the construction of a cadmium cell. The H-form of cell is the most convenient to fill; and the method of sealing the cell with small blast flames is so simple that the two legs may be hermetically sealed at the top without the least danger of affecting the contents of the element.

The glass parts can be readily made by anyone possessing a little skill in glass-blowing. Fig. 1 shows the cell ready to be filled. The tubing is drawn out and contracted at *a* so as to leave the diameter about 6 mm. and with thin walls at this point. Fragments of the cadmium amalgam may be introduced into the clean dry cell, and may then be melted by dipping the leg of the cell into hot water; or the amalgam may be melted under cadmium sulphate solution, and may then be introduced in the liquid form by means of a small tube, slightly contracted at the end, and of a diameter that will allow it to pass freely through the neck *a*. This tube is used as a pipette; it permits the melted amalgam to be introduced rapidly and without splashing. The mercury, the thin paste, and the concentrated cadmium sulphate solution may be introduced in the same manner. An alternative method is to introduce the materials through little funnels made out of small test tubes. The funnels must pass through the neck *a* of the cell and must reach well down toward the bottom.

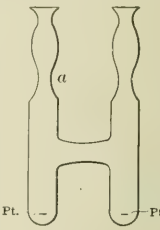


FIG. 1. CADMIUM CELL.

The electrolytic mercurous sulphate, which has stood with mercury under dilute sulphuric acid, is brought into a Gooch crucible, avoiding free mercury, which interferes with the filtering; it is then washed first with sulphuric acid (made by adding 0.5 c. c. concentrated H_2SO_4, density 1.84, to a liter of water), and then with concentrated cadmium sulphate solution. (Dr. Carhart remarked in parenthesis in this connection that water is a most dangerous thing for many purposes, even for washing.) It is better to reject the top layer, which may be slightly darkened. The paste is next made in a clean agate mortar by grindnig together crystals of $CdSO_4 8/3H_2O$, and a little mercury, and then mixing in about three volumes of the mercurous sulphate and enough saturated cadmium sulphate solution to make a thin paste. After the mercury under dilute sulphuric acid, is brought into side of the cell, both legs are filled up to the cross tube with the dry, clean crystals of $CdSO_4 8/3H_2O$. Enough of the saturated cadmium sulphate solution is finally added to fill the cell to the top of the cross tube. The sealing-off is readily done by means of two small horizontal blast flames, 3 cm. long, directed in a line toward each other and just meeting. The narrow part *a* of the cell is brought between the impinging flames, the glass quickly softens, and the top part is drawn off. There is no noticeable heating of the contents of the cell; but it may be advisable, before one has acquired the proper skill, to protect the cell by an asbestos disc fitted to the tube below the point *a*. The disc is not necessary if the cell is made like the one shown in Fig. 1. A cell sealed in this way contains nothing except the materials of the voltaic combination. It cannot leak, and can be immersed in kerosene without danger of the oil getting inside. A perfect seal has always been a most difficult thing to secure.

The authors give in tables the results obtained with such cells, and these are extremely good. A series of cells set up in January do not appear to have changed since then by more than one part in 100,000, and the agreement among themselves is exceptionally good. The e. m. f. is 1.01008 international volts at 21.1° C. These cells do not require any ageing process to reach their equilibrium e. m. f., but reach it immediately. This is quite different from the behavior of cadmium cells in which other kinds of mercurous sulphate are used. The author

finally expresses his opinion that mercuric ions are always present, and that there is always equilibrium between mercury, mercurous ions and mercuric ions. Quite recently, the authors have set up fifteen Clark cells with the new mercurous sulphate, but the results were not yet given.

In the discussion which followed, Mr. H. N. Potter asked what kind of glass the authors had used for the containing vessel. Glass is not a well defined substance, and since we have now quartz-glass, we could use it. Under these circumstances there could be no changes from country to country on account of differences in the glass. Prof. Carhart replied that he thought they had always used the same glass for the cells, but had not considered this to be very important, since they did not expect much variation from the glass. Dr. J. W. Richards asked about the accuracy in determining the temperatures, whether a mercury or gas thermometer was used. Prof. Carhart replied that this was not of very great importance for the Weston cell and a good mercury thermometer is sufficient. Dr. F. A. Wolff stated that he had not yet set up cells with the electrolytic mecurous sulphat, but from its crystalline character and from its chemical purity he considered it specially suitable for standard cells. Prof. Carhart suggested that if the cadmium cell is adopted as a standard of e. m. f. we should call the saturated type, with an excess of crystals, the "Weston cell, primary standard," and the other unsaturated type we should call the "Weston cell, secondary standard." Mr. Carl Hering asked whether there is not an uncertainty introduced by hermetically sealing the cell, since this might produce a change of pressure which might react upon the e. m. f. Prof. Carhart replied that this was apparently disproved by the uniformity of the results obtained; moreover, from the construction of the cell there can be no difference of pressure at different points of the cell. The hermetically sealing of the cell is done near 20° C. Dr. Richards concluded from this that the pressure inside the cell must be smaller at ordinary temperature.

SINGLE POTENTIALS OF THE HALOGEN ELEMENTS.

A paper on this subject was presented by Mr. WILLIAM ROY MOTT, who pointed out that "there are many points in the ionization theory not in harmony with some facts observed in the study of single potentials." He thinks that "the impossible solution tensions assigned to metals tend to blind one to the fact that the actual chemical reaction taking place, and its free and bound energy are the essential points." Dr. Patten and the author have calculated the single potential of chlorine for dilute aqueous solution as — 2.00 volts. By similar methods the author has calculated the single potentials of the other halogen elements: Iodine,—0.89 volts; bromine,—1.53 volts; fluorine, — 2.53 volts, all being referred to Ostwald's zero. The author then discussed decomposition voltages and gave a diagram reproduced in Fig. 2, with the decomposition voltages as abscissae and the single potentials of the metals as ordinates. The decomposition voltages are calculated from the thermochemical data simply by Thomson's rule. This diagram represents the well-known additive law. Equal increments mark the displacement of one metal by another metal, or of one halogen element by another halogen element. This results in two sets of parallel lines. This diagram can be used in the calculation of any one of the factors—the total decomposition voltage, the single potential of the anion, and the single potential of the cation—when the other two factors are known, but it must be remembered that the formation of normal salts in dilute aqueous solution is postulated.

The author then discussed the various experimental determinations of the single potentials of the various anions, the values of which were given above. In conclusion the author stated that the additive law holds much better for dilute aqueous solutions than for solid salts. Solid salts may, in different forms, possess very different amounts of energy; for example, amorphous silver iodide has a heat of formation of 6.6 large calories, while the crystalline variety has a heat of formation of 16.2 large calories. This introduces a difference of 0.33 volts in their corresponding decomposition voltages.

The difference between the decomposition voltage of the solid salt and of the dissolved salt represents the heat of solution or the energy of the reaction resulting from the affinity of the salt for the solvent. Other solvents than water have very different heats of solution. Solubility is largely determined by the mutual affinity of the solvent and solute as represented by the heat of solution.

Dr. R. Gahl remarked that the method of the calculations of the author is in some points open to objections on the basis of the principles of thermodynamics. Mr. Mott replied briefly.

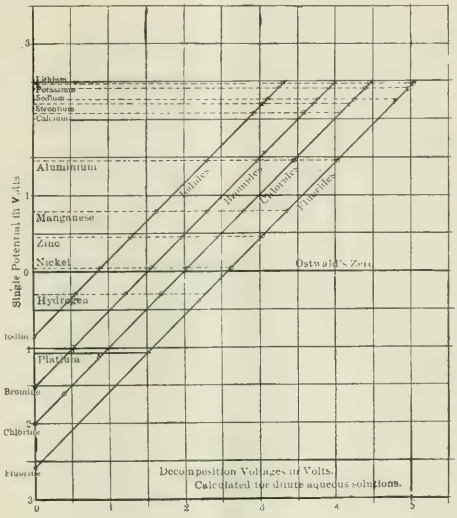


FIG. 2. DIAGRAM OF DECOMPOSITION VOLTAGES

THE CONTINUOUS ADVANCE OF ELECTROCHEMISTRY.

At a special meeting held on Thursday evening, the retiring president, Prof. J. W. RICHARDS delivered his presidential address on the above subject. He remarked that the field of electrochemical activity covers three distinct lines of endeavor, namely, investigation and classification of electrochemical phenomena; the building of a comprehensive electrochemical theory; and the application of electrochemistry to industrial needs. He discussed briefly the past achievements in each of these main fields of electrochemical activity, in order to determine therefrom and to discuss more at length the present bent and probable future direction of each.

Concerning the experimental investigation and classification of electrochemical phenomena he expressed the opinion that electrochemistry has lost much in the past by lack of co-ordination and co-operation of electrochemists. An attempt to give a complete summary of what has been done in the past is now being made in the German Handbuch, which is in course of publication. On the other hand, the foundation of electrochemical societies in this and other countries will bring good fruits, since it is their function to bring electrochemists together. There has been an army of investigators in the past, but the results would have been more valuable if the army had really been an army directed by a leader. There are now large gaps in our experimental knowledge of the various fields of electrochemistry, and these must be filled by experimental research in the near future. Dr. Richards gave a list of many subjects which need systematical attack and orderly study; among them are investi-

gations of the electric conductivity of some common salts, of fused salts, of solutions of salts in fused solvents, the use of accurately controlled electrodeposition for the purpose of determining the chemical equivalents of metals; the calorimetric determination of electrolytic cells in operation; the deposition and solution of alloys; the behavior of mixed electrolytes; the relation of viscosity to conductivity; the solubility of metals in their own fused salts; the modus operandi of porous diaphragms. The author referred to the work of A. A. Noyes on electric conductivity of solutions at high tempera- and to that of L. Kahlenberg on non-aqueous solutions.

Concerning the evolution of a comprehensive electrochemical theory, Dr. Richards expressed the opinion that we are now in a transition status. We know what we are abandoning, but we do not know what we are getting at. Scientific theories must always be in a constant flux. Concerning the dissociation theory he said that he does not know whether it is true, but that it would be wrong to claim that it is certainly true. His own conception of the state of a solution is that the solute is in an abnormal physical state, having resemblance to the gaseous state, and that in some cases a definite compound of the solute with the solvent exists in solution, it also being in the abnormal physical but not abnormal chemically. Large generalizations are very seldom proven directly false. Facts accumulate as evidence of the inefficiency of a theory in certain directions. From J. J. Thomson's recent work on the structure of atoms one might think that the ionic theory might be replaced by the electronic theory. The author referred to J. H. L. Vogt's investigations on the nature of fused silicates. The physical solution of one substance in another covers a large field of what was formerly considered to be entirely chemical in its nature. The eutectic mixtures resulting are in no sense chemical compounds.

JOSEPH W. RICHARDS,
Retiring President American Electrochemical Society.

The concluding part of the lecture dealt with the application of electrochemistry to industrial needs, the author briefly referred to the most important electrochemical industries, like copper refining, the manufacture of calcium carbide, aluminium, sodium, alkali and bleach, chlorate. Electrochemical methods represent a new instrument for getting old or new results. In the electric furnace we can produce temperatures which were never before thought practical. Among the electrochemical processes we may distinguish those methods applied to the more powerful chemical compounds which cannot be easily decomposed by other means; high temperature reactions; ordinary chemical processes in which the directness of the electrochemical influence is deciding. The author gave examples of these three classes. The first comprises the treatment of those fixed and difficultly transformable compounds of strong metals, of large occurrence in nature. What electrochemical methods can do in this respect is evidenced by the history of the metallurgy of aluminium, which shows the potentiality of electrochemical methods for improvements. After the purely chemical process had spoken its last word concerning the manufacture of aluminium, electrochemists started and won the day. Dr. Richards referred at some length to the production of metallic silicon on a commercial scale by the Tone process in Niagara Falls. Only by electrochemical methods it is possible to get cheap silicon, which occurs in its compounds in an enormous amount on the earth. The problem is now to find uses for silicon just as it was ten years ago to find uses for aluminium. While the electrochemist is the reverse of a nihilist he is a typical and convicted revolutionary.

The maufacture of steel by electric furnace methods is most promising in countries where fuel is dear and power cheap, and afterwards in localities where very cheap power is being generated by gas engines using either the waste gases from blast furnaces or producer gas made from coal waste or culm. Even before that time the auxiliary use of electric heating to take off "the peak of the load," so to speak, in our open-hearth steel furnaces, that is, to furnish the last few hundred degrees of necessary temperature, while the combustion of gas furnishes the lower range, is a distinct commercial possibility. Already our steel plants are a network of electrical appliances for running cranes, charging machines, hoists and cars, and the step is not a long one to employ this already present agent to help the heating gases over the heaviest part of their work, the bringing up of the charge to tapping heat.

The author briefly referred to electrochemical methods producing calcium, magnesium and beryllium. We are only beginning to appreciate the possibilities of calcium which is the most powerful pyrochemical agent at temperatures, above red heat, the strongest metallic base existing. An electrolytic production of magnesium would reduce its price enormously and enlarge very considerably its uses. There would be a large number of applications for beryllium if it could be obtained cheaply. Calcium carbide is practically a new compound, but it is only one of numerous carbides, carborundum being another one. Other carbides may equally find applications.

The author referred to a remark made to him by one of the most vigorous and industrious electrochemists that we are so overwhelmed by new things of possible use to science and industry that we can at most investigate only a small fraction of them. Electrochemistry is a virgin continent of undeveloped possibilities. The great services which electrochemistry has rendered humanity and the march of civilization in the few decades which measure its brief but phenomenal advance, are but a fraction of what is yet to be accomplished. The author concluded his address as follows: If in the battle of industrial competition, you are summoned by the conservatives of industry to strike your colors, answer with a courage and determination of the intrepid Captain John Paul Jones, "Surrender, sir? We have only begun to fight."

The Composition and Resolution of Voltages.

The first paper of the Friday session was presented by Prof. J. W. Richards on the above subject. It contained an elaboration of the theory developed by him in a former paper read before the Philadelphia section of the Society (abstracted in Electrochemical Industry, March, 1904, p. 95). The problem discussed by the author is how to generalize Thomson's rule so as to apply to the case that several different electrochemical actions are simultaneously going on. The author, therefore, does not pretend that his theory is of greater exactness than the original Thomson's rule since any thermoelectric effect is purposely neglected.

The author discussed his method on the basis of examples taken from commercial practice. He first considered the case that several actions are simultaneously going on at the anode, i. e., what he calls the composition of voltages at the anode. His first example was the refining of impure metals, and he dealt with the case of an impure copper anode, containing 90 per cent Cu, 5 per cent Fe, 1 per cent Ni and 1 per cent Zn. If the materials in the anode dissolve in this ratio, then, if we base our calculations on a certain number of coulombs passing

through the tank, we can calculate the amount of copper, iron, nickel and zinc passing into the solution at the anode. For each of these four different anodic reactions the cathodic reaction is that an equivalent quantity of copper is deposited. Now it is easy to calculate from thermochemical data the energy corresponding to each of these four reactions. If we neglect concentration differences at the two plates, the solution of copper at the anode, and the deposition of the same amount of copper on the cathode neither consumes nor evolves energy. The other three reactions evolve energy (each of them could be used separately for making a primary cell). If we sum up the energy evolved by the last three reactions and give the figure in joules or volt-coulombs, and then divide this figure by the number of coulombs which we have taken as the basis of the whole calculation we get the "composite voltage" of the total process. Prof. Richards finds that the last three reactions represent an assisting voltage of + 0.065 volt; copper refining would therefore need no external energy under these conditions, if there was not a loss of volts due to the internal resistance of the cell and also a loss of volts due to concentration differences at the two electrodes. His second example was the numerical calculation of the solution of a copper-nickel anode with the deposition of copper on the cathode. This is one of the steps of the Browne process (ELECTROCHEMICAL INDUSTRY, July, 1903, page 382).

The author then discussed the case that at the anode only one action takes place, while several reactions occur simultaneously at the cathode. The first example given was the electrolysis of a mixed solution of copper nitrate and silver nitrate, with a pure copper anode and deposition of a copper-silver alloy on the cathode. Another example is when in the cathodic deposition of a metal hydrogen simultaneously appears at the cathode. Thus, in depositing copper from an aqueous solution, the voltage is constant as long as only copper is deposited. If, however, the solution becomes poor in copper near the cathode (perhaps on account of high cathodic current density), then we have both deposition of copper and evolution of hydrogen, and the voltage begins to rise according to the ratio of the amounts of copper and hydrogen deposited on the cathode. The author emphasized again that his method of combining and resolving voltages is essentially a method of combining and resolving energies.

In the discussion Mr. Lawrence Addicks stated that Dr. Richards' theory well represents what is observed in copper refining. Mr. W. R. Mott remarked that various points might change the calculations; for instance, concentration changes. Sometimes we have at the anode a purely chemical dissolving action (local action). The heat of alloying should also be taken into account as it is sometimes large; also the so-called over-voltage. Mr. Carl Hering thought that Dr. Richards' calculation appears to be based too much on theory. In the example of copper refining where zinc and iron are in the anode there would be surely local action. He thinks those factors which are not considered in Dr. Richards' theory may become in practice great compared with the small amount of voltage calculated by him (0.065 volt in the copper-refining case) so as to obscure entirely the results of his calculations. Mr. Reed remarked that the actual figures calculated by Dr. Richards in several cases agree almost absolutely with what he has found by experiment. Dr. R. Gahl said that if one makes a calculation on the basis of the ionic theory, the results would be different from those of Dr. Richards' calculation; he expressed this by stating that while Dr. Richards' law calls for a straight line in a certain case, the ionic theory would call for a bent curve. Mr. Reed stated that according to experiments, the curve in that case is practically a straight line. Mr. Addicks stated that the experience in copper refining speaks against Dr. Gahl. Dr. Gahl replied that his curve is based on the assumption that no alloy is formed, and that to apply it to practical results, it must be modified. Mr. Hering referred to a method of depositing zinc without hydrogen. Dr. Richards replied that for applying his theory to practical cases, of course, such factors like heat of alloying, the e. m. f. loss due to internal resistance must be taken into account, but he was purposely not dealing with them in his paper. He also stated that his paper is not altogether theoretical since he has often observed such results as he has calculated. Replying to Dr. Gahl he said that in his calculation he assumes a continuous process, like that of Browne, while in a case like that assumed by that of Dr. Gahl the constitution of the electrolyte continually changes and one component is gradually more and more exhausted.

MOLECULAR CONDUCTIVITY.

In a paper on this subject Mr. C. J. REED emphasized that electrical conductivity is a property of matter, which, like transparency, diathermacy, magnetic permeability and heat conductivity, can be measured and compared in different substances only by employing a unit in which there is a definite section, across which the flux is measured, and a definite length in the direction of the flux. Units of this kind must be defined by certain relations of form, in which the ratio of length to cross-section is a fixed ratio. It is, for example, impossible to compare the conductivities of iron and copper by measuring the conductance of a pound of iron and the conductance of a pound of copper, without any reference to form, or dimensions. What is true of a pound of iron or copper is equally true of a grammolecule. But Mr. Reed thinks that those electrochemists who talk about the molecular conductivities of solutions in different degrees of dilution absolutely lose sight of this fact. "The conductance of a liter of solution, containing a grammolecule is measured in the form of a flat prism, one centimeter thick and having a crosssection of ten square decimeters. This conductance is taken as the conductivity of the normal solution. Dilutions are made by adding water and spreading out the increased volume, whatever it may be, into a flat plate of the same thickness, one centimeter, and increasing the cross-section in proportion to the increased volume. The conductances of these extended volumes measured between the parallel sides are called 'molecular conductivities' merely because the measured volumes contain a grammolecule of the solute." He compares this with a method in which one would measure the conductance of a certain cube of silver between opposite faces, would then fuse the silver with 200 times its volume of lead and measure the conductance of the resulting alloy between faces having 200 times the area of the original faces, and would then conclude that the conductance so measured represents the molecular conductivity of th silver in the two conditions of concentration.

CHARLES J. REED

Retiring Secretary American Electrochemical Society

Mr. Reed claims this is what is done by the electrochemist when he speaks of the molecular conductivity of solutions. He emphasizes that in an aqueous solution one cannot say that it is the solute alone which conducts the current. Mr. Reed thinks that the use of deductions based upon quantities like molecular conductivity have been very harmful, since they have produced a fundamental confusion in the development of the electrolytic dissociation theory. He quotes several state-

ments from which he concludes that in books on the dissociation theory the term conductivity is often used where we should read molecular conductivity and that moreover the conclusions on the increase of the degree of ionization with dilution is based upon such a confusion. Mr. Reed argues that the increase in molecular conductivity with increased dilution does not require any increase in "conducting power" and, consequently, does not require any increase in the number of ions. He argues that the conducting power (meaning evidently the conductivity) and, therefore, the number of ions rapidly diminish with dilution, but the change in the form and dimensions of the conducting mass caused by increasing dilution, according to the method used in molecular conductivity measurements, results in measurements of conductance which slowly increase with dilution. Mr. Reed concludes that in view of the facts it seems to him that the term "molecular conductivity" and all theoretical deductions based on investigations of molecular conductivities of different degrees of dilution have no physical significance.

In the discussion Mr. Carl Hering said that one finds in practice often loose statements, and that one should carefully distinguish between conductance (measured in reciprocal ohms) and conductivity. The conductance of a body depends upon its form and the direction of the current while the conductivity of a substance is a property of matter.

Dr. E. F. Roeber agreed that the general remarks in the first part of Mr. Reed's paper were correct, and their correctness was beyond dispute, but he strongly disputed the conclusions drawn therefrom by Mr. Reed concerning the method of measuring molecular conductivity of solutions and concerning the validity of the dissociation theory. He gave a mathematical development to show that if we once accept the model of traveling ions, we are lead with absolute consequence to an equation, stating that conductivity equals concentration (in gram equivalents per liter) multiplied by i multiplied by $u + v$, where u and v represent the mobilities of the cation and anion, respectively, and i represents that proportion of the dissolved molecules which takes part in the conduction of the current, or, in other words, the degree of ionization. In this equation a constant factor is left out which depends only upon the units chosen. From this equation it follows directly that molecular conductivity, *i. e.*, the conductivity divided by concentration, equals i multiplied by $u + v$. What we measure in practice, is always a conductance, but from the conductance we can calculate the conductivity, and by dividing it by the number of grammolecules per liter we get the molecular conductivity. The method of measuring molecular conductivities which is attacked by Mr. Reed follows directly from the definition of molecular conductivity since the cross-section across which the conductance is measured is inversely proportional to the concentration. What is found by experiment is that the molecular conductivity increases with increasing dilution. Hence, according to the above equation, $i\ (u + v)$ increases with dilution. If we assume that all dissolved molecules participate equally in the conduction of the current through the electrolyte, then i is unity and we must conclude that the mobilities u and v increase with dilution; this is how Kohlrausch first expressed his experimental results. If, however, we assume Arrhenius' theory that only a certain number of the dissolved molecules transport the current, and that the mobilities u and v are independent of the dilution, then since $i\ (u + v)$ increases with dilution, and u and v are constant, it follows that i must increase with dilution, that is that the degree of ionization i increases with increasing dilution, and nothing more has been claimed in the statements attacked by Mr. Reed. There is, therefore, no confusion whatever concerning this point. But even if we do not accept the model of traveling ions it would be wrong to deny the physical significance of molecular conductivity. If we consider the conductivity of a dilute solution as a function of the (large) amount of solvent a and of the (small) amount of solute b, then we may develop the function in form of a series and need to consider only the first two terms on account of the supposition that the solution is very dilute. We get $f(a + b) = f(a) + b\,f'(a)$, where f' means the first differential quotient. In the case of water we may approximately assume the conductivity of pure water to be zero, so that $f(a)$ becomes zero, and we see that the molecular conductivity is represented by $f'(a)$. For more exact measurements we cannot neglect the conductivity of water, but must subtract it from $f(a + b)$. This is what Kohlrausch did in working out his results.

Dr. R. Gahl thought that Mr. Reed's difficulty might be due to the fact that if we want to calculate molecular conductivity for infinite dilutions, we have a quotient of the conductivity (which for infinite dilution becomes not zero, since pure water has a certain conductivity) to the concentration (which becomes zero at infinite dilution). This would lead to an infinite value of the mobility, but this result is wrong, since we must deduct the conductivity of the pure water from the conductivity of the solution; this is what Kohlrausch does. Dr. J. W. Richards thought it was objectionable to simply subtract the conductivity of the pure water from the conductivity of the solution. Dr. Gahl replied that this method is correct for very dilute solutions, and is justified by the consistent results obtained by Kohlrausch. Col. S. Reber thought that the formula molecular conductivity equals $i\ (u + v)$ is only a mathematical expression, the physical significance of which might be denied. Dr. E. F. Roeber replied that the physical significance of the i, considered as degree of ionization, is emphasized by the fact that for very dilute solutions, measurements of the lowering of the freezing point or of the raising of the boiling point give us the same values of i which we find from molecular conductivities.

The Economic Balance in Electrolytic Copper Refining.

A paper on this subject was then presented by Mr. Lawrence Addicks of the Raritan Copper Works. He remarked that probably few persons not in daily contact with refining work realize the close interdependence of relations which forms what he terms the economic balance. He proposed to indicate these relations and their bearing on the cost of production. The problem may be separated into three variables—tank resistance, age of electrodes and current density.

Tank resistance is made up of metallic conductors, contacts, anode slimes, counter e. m. f., electrolyte and a negative quantity due to imperfect efficiency. The metallic conductors consist of the leads from the generators, the circuit bars and rods supporting the electrodes, and the electrodes themselves. The chief item here is in the circuit bars running from tank to tank. This resistance can be lowered either by increasing the section of the bars, or by increasing the number of tanks abreast. The first method is limited by the cost of the copper required; the second involves a consideration of the increased labor cost due to inaccessibility, the loss in output caused by the increased number of tanks which have to be cut out of electrical service when changing electrodes or removing slimes, and, finally, the saving in first cost of plant.

The loss from contacts depends on their number, the weight bearing down and the condition in which they are maintained. The number depends upon whether or not the anode is provided with supporting lugs—if so, the weight of scrap made is proportionately increased. The average weight depends on the age of electrodes. The condition is governed by the labor expended in shining, and by the exposure to moisture and fumes, or, in other words, by the temperature of electrolyte. The resistance due to slimes adhering to the anode is a very variable one, and depends, of course, upon the thickness of the layer allowed to form upon its surface. Very impure anodes and a high current density give great trouble. Counter electromotive force is due chiefly to the difference in concentration at the electrodes. Circulation tends to check this, but no amount of circulation will obliterate it.

The resistance of the electrolyte itself depends upon composition and temperature. Resistance varies greatly with changes in the chemical composition. In deciding upon the composition to be maintained, we are governed largely by the impurities in the anode copper. Arsenic is the most difficult to handle. With small quantities of arsenic present in the anode the electrolyte may be maintained reasonably pure without a special purifying process, the quantity of arsenic slimed balancing that introduced at the anode before the per cent arsenic in the solution reaches a troublesome amount. A high current density magnifies these difficulties. The amount of copper carried as sulphate by the electrolyte must be sufficiently in excess of the arsenic to insure satisfactory purity in the cathode at the tank voltages existing. In free acid contents we are also limited by the decomposition point—a percentage at which electrolysis of water commences with resulting polarization.

The temperature coefficient is large, and we have a balance to strike between power saving, cost of heating, increased contact losses, and increased cost of keeping the copper contents of the electrolyte down to the required figure. When considering the saving in power from heating the electrolyte, we must not lose sight of the fact that we are dealing with but part of the total resistance of the circuit. Starting at the generator terminals, if we have an electrolyte of low resistance and an anode running high in impurities, the liquid resistance may not greatly exceed 50 per cent of the total. With a different set of conditions it may be 80 per cent, or more, but in any case this factor must be reckoned with. The spacing of the electrodes, or, in other words, the thickness of the liquid column, has a great deal to do with tank resistance; it must be considered in connection with age of electrodes and current efficiency.

A diminishing current efficiency forms an effective, but somewhat expensive, way of arriving at a low tank resistance. It must be remembered, however, when deciding upon the efficiency which it pays to maintain that the loss in output from this cause is accompanied by a certain diminution in total power charges.

As to the question of age of electrodes, much depends upon whether or not the refiner is charged with interest on the metals tied up in the process. If so, he will use a lighter anode than otherwise, though the question of current density must be taken up at the same time. A heavy anode reduces the percentage of scrap and the handling charges, as it is the number of electrodes, rather than the pounds of electrodes that figure in tank-room handling. The heavier the average weight during life the better the contacts. With the cathodes smoothness of deposition is the governing factor, as upon it depends the current efficiency. The smoothness depends upon age, electrode spacing, current density, circulation and composition of electrolyte. On the other hand, as the age decreases, handling charges and the cost of stripping starting sheets runs up. As a partial offset to the increased number of stripping tanks required per hundred depositing tanks, there is the very high current efficiency obtained in these tanks due to the rigidity and low age of the cathodes.

Finally, from the standpoint of current density the problem becomes largely one of output. With any given plant the simplest way to increase the output is to raise the current density. Even our largest plants still have a respectable proportion of fixed charges, and the distribution of these over a larger tonnage is always an attractive proposition. If interest charges are involved, we gain here as well. With a rising density, however, we are met by a rapidly-increasing power cost and a roughening of the deposit. The small counter e. m. f. present keeps the power needed per tank from increasing quite as the square of the current density, but it approaches this ratio. The rougher cathodes require a readjustment of several of the conditions previously outlined, involving a corresponding increase in costs in order to maintain the current efficiency. The circulation must be pushed, and this is followed by increased silver losses in the cathode—a charge which mounts rapidly. 0.1 ounces or 1.5 ounces per ton might be equally good work for different sets of conditions. The increased energy expended in the cell brings the temperature up and helps the tank resistance. As the density increases the relative cost of operating insoluble anode tanks decreases.

In any given case the multiplicity of relations pointed out must be solved, a pair at a time, and a set of final heats run off with the winners. We are very much in the same position as when, in hydraulics, we wish to compute the flow over a weir. The velocity of approach enters into the formula, but this presupposes a knowledge of the flow. We use an estimated flow to find this velocity and then solve the equation for the real flow. This figure is used in computing a corrected velocity of approach and so on till the true value of the flow is obtained. In the light of the foregoing it is easy to see why no two refineries use just the same densities and temperatures and so on. A difference in the cost of labor or power or supplies would tip the economic balance to a new reading at once. The situation varies also according to whether or not the refinery is operated by a copper producer. If it is, interest charges on the metals tied up must be reckoned with and the question of output is not so vital, as it cannot exceed the quantity furnished by the smelter. If the plant is a custom one, operated on a toll basis, a period for refining is usually allowed gratis and interest questions, within certain limits, do not arise.

And, finally, when all is said and done, the lowest cost per ton may not be the cheapest cost per ton. This seeming paradox is due to the fact that with a current density somewhat greater than that giving the lowest cost per ton, the output may be sufficiently increased to give greater earnings in spite of the higher cost per unit.

In the discussion of Mr. Addicks' paper, the secretary presented a written communication by Prof. W. D. Bancroft, who questioned whether Mr. Adicks gives in his paper an accurate statement of the things as they are. Not a series of successive solutions of single parts of the problem should be attempted, but the whole problem should be attacked at once. He thought that Mr. Addicks had not given all the factors, while some of those mentioned by him were relatively unimportant, and pointed out the great difference of operation at the Anaconda and Great Falls plants in spite of the fact that they are near together, so that some conditions are surely equal. Mr. Addicks, in reply, thought that the difference in practice of these two works confirms his views. He pointed out that the final economic balance is the summation of balances. He does not veto a high current density, but only too high a current density. Mr. Carl Hering thought that the only really satisfactory way in case of so many variables is to work out the problem for a great many different conditions; we can then learn much by taking two and two together. Mr. Addicks emphasizes that a final curve for the economic balance can only be obtained by first plotting all the individual curves.

Heat of Neutralization.

A brief paper by Mr. G. W. Westman was then presented in which some critical remarks were offered on Prof. J. W. Richards' theory of the heat of neutralization, as presented in a former paper (Electrochemical Industry, 1903, page 491). The author discussed this theory on the basis of a molecular hypothesis of his own. For instance, he considers diffusion as depending on the centrifugal force of the rotary movements of the molecules, which force acts against gravitation. From his point of view he shows that Dr. Richards' method of calculation is open to criticism. He also objects to the statement that ionization is in no sense to be regarded as a resolution or decomposition of the molecules into the constitutents. "As in the case of gases, the ether separates and supports the molecules in exercising the centrifuga. .orce, so in the case of solu-

tions the water separates the molecules from each other, in order that their centrifugal force can act, which is not possible when they are bound together. When more water is added the molecules expand farther and their constitutents are farther removed from each other, so that the attraction between them grows less."

In the discussion, Prof. Carhart thought that the author's conclusions are based on "most extreme theories." Dr. Richards considered that the last statement of the paper is a confirmation of his own views, namely, that the state of solution is similar to that of gases.

The Energy of Ions.

A paper on this subject was presented by Prof. Louis A. Parsons, of the University of Utah. In the absence of the author it was read by Mr. S. S. Sadtler. The paper was essentially a reply to criticisms which Mr. C. J. Reed had formerly made against the electrolytic dissociation theory on the basis on the energy principle. The author summed up Mr. Reed's argument as follows: "Two oppositely-charged bodies constitute a source of electrical energy. When they are discharged through an intervening medium energy is evolved or work done upon that medium. If, according to the accepted theory, ions are charged, in the formation of atoms from ions, the latter must be discharged, thereby adding energy to the circuit. In all known changes from ions to atoms there is an absorption of energy from the circuit, and not an addition of energy to it. Therefore, ions must be uncharged and atoms charged."

The author's reply to this argument is very long and highly theoretical. He first accepts Mr. Reed's premise as to what the ions are and endeavors to show that if Mr. Reed is right in saying that in all known changes from ions to atoms there is an absorption of energy from the circuit, then the only legitimate conclusion is that ions are discharged and atoms are not, which is diametrically opposite to Mr. Reed's conclusion. The author does not believe, however, that we are justified in considering the ions as spheres or small bodies with positive and negative charges on them, and the atoms as these spheres "discharged" in the sense of having given up their charge to some external body. It does not follow from the ionic theory and is certainly opposed to the electron theory. In a sodium chloride molecule we may assume the sodium atom still combined with a positive electron, and the chlorine ion combined with a negative electron, but we call this molecule electrically neutral, because no electric field is due to the two opposite electrons in the molecule. The author shows how the electronic theory leads to the conclusion that in a solvent of a high dielectric constant the ions in a molecule will tend to separate from each other.

The author then remarks that there is a great deal of evidence that the atom, ion and molecule are much more complex than is generally supposed, the atom being a rather complicated system in itself, containing electrons or "atoms of electricity" revolving in orbits of their own. These electrons possess electro-kinetic and electro-potential energy. The energy of ions and molecules may then consist of several different forms besides the energy of the external field due to charged ions. Unless we know all about the energy in the two cases we cannot arbitrarily say that the energy of "charged" ions must be greater than "uncharged" molecules or even atoms. We could never be justified in such an assertion until we had shown the sum total of all the energy in a molecule or uncharged atom must necessarily be less than the energies of the charged ion. We must take into account the electropotential and electro-kinetic energies of the electrons, the mutual energies of the different electrons, the mutual energies of the electrons and atoms, and the mutual energy of the atoms in the molecule besides the energy of the external field.

The author concludes that the ionic theory for solutions has proven very fruitful, although he does not maintain that it is perfect or not incapable of improvement. Since no better theory has been offered as a substitute it should be allowed to stand until something obviously better is offered in its place. If it has not been proven to be true, certainly it has not been shown to be impossible. It does not necessarily violate either the conservation of energy or any other established theory of physics.

In the discussion which followed, Mr. C. J. Reed said that he did not find anything in the paper he would criticize in connection with his former criticisms. He claimed that what Dr. Parsons had offered was not the dissociation theory, but Parson's own theory. Messrs. G. L. Cabot, J. W. Richards, E. F. Roeber and R. Gahl also participated in the discussion, the latter two defending Parsons' paper and the dissociation theory. Dr. Gahl expressed the opinion that if one accepts the electron theory, some difficulties which might be found in the conception of the ion would disappear.

Aluminium Electrolytic Condenser.

A paper on this subject by Mr. C. I. Zimmerman was read, in the absence of the author, by Mr. A. B. Marvin.

After some brief remarks on the well-known property of the aluminium electrode, which permits a current to pass in one direction but not in the other, and a brief discussion of non-symmetrical cells in general, the author gave some notes on the film which causes the peculiar behavior of the aluminium electrode. This film, which is probably an oxide, has a thickness which could be measured by interference phenomena and was found to be between 0.000005 and 0.00005 cm. Its dielectric constant has also been determined and found to be pretty large (Mr. Mott gave afterwards, in the discussion, its value as 10).

The author then gave an account of experiments which he has made with the aluminium electrolytic rectifier, which is essentially a combination of two aluminium electrodes, while the electrolytic rectifier consists of one aluminium electrode and one iron electrode. As electrolyte a solution is used which allows the film to be reformed by electrolytic action. The author pointed out that a constant charge is held at all times in the condenser when connected to an alternating-current circuit, and gave the experimental proofs of the presence of the charge. The condenser action was shown to be due to energy variations alone, and not to coulomb variations. The aluminium electrolytic condenser was then briefly compared with tin-foil condensers and the losses in the electrolytic condenser which were classified into resistance losses, leakage losses, and film losses were briefly discussed. They increase about proportionally to the frequency of the current. On account of the electrolytic reformation of the film, any punctures which occur in the film, are automatically repaired. While in one case the author succeeded in constructing a condenser which could be used up to 1250 volts, electrolytic condensers should not be used at a higher voltage than about 150. The author obtained an efficiency as high as 97 per cent, but when operating a condenser at not more than 110 volts in continuous operation, one may expect an efficiency of 95 per cent. The capacity is about one-quarter to one-half microfarad per square inch of surface of a single electrode.

This paper was the last read in the Friday session, and its discussion was taken up on Saturday morning. Mr. W. R. Mott referred to the well-known Graetz rectifier arrangement which enables one to utilize both the positive and negative half waves of an alternating current for rectifying purposes and stated that it was patented in the United States in 1891 by Mr. T. D. Bottome (September 1891). He exhibited samples of the aluminium film on glass. While having the color of aluminium for reflected light, it is quite transparent. Not sufficient material of the film has yet been collected to enable one to make an accurate analysis. The leakage loss is due to small points in which the film is ruptured. He made some suggestions as to the effect of previous treatment; for in-

stance, it would be interesting to use a condenser first at 20 volts, then at 100 volts, and then again at 20 volts, and to see whether the old results are again obtained. He also spoke of the use of the electrolytic condenser as a phase splitter. Mr. E. E. F. Creighton referred to the dielectric constant of the film which is much higher than that of other solids, and asked whether it was not, perhaps, due to gases occluded in the film. Dr. K. E. Guthe stated that he had actually fund gases in the film (ELECTROCHEMICAL INDUSTRY, vol I., 1902, page 48), but Mr. Mott thought that the experimental arrangement of Dr. Guthe did not show conclusively that the gases given off did really come from the film. Dr. Guthe remarked, however, that after the gases had been removed the resistance of the film was very much reduced. Dr. J. W. Richards asked whether this might not point to the fact that when operated under a high atmospheric pressure the condenser would be more effective. Dr. R. Gahl said he had used aluminium cells as condensers in measurements of the resistance of cells, but had found them to be not constant. Mr. Mott stated that the leakage current, while depending upon the nature of the electrolyte, is very small at low voltages in certain solutions like phosphate, etc., but when one comes near the critical voltage the leakage current becomes large.

STUDY OF THE ELECTRIC ARC.

A highly interesting paper on this subject was presented by Dr. WILLIAM S. WEEDON, of the General Electric Company. He has studied the so-called flame arcs between metallic electrodes. This class, as distinguished from the crater arc of the ordinary carbon lamp, is especially interesting, since it is possible to follow the changes in the character of the light as the conditions are altered.

One very important problem is the amount of material which is transported during the running of the arc. In air it is quite large for most materials. The rate of waste of carbon is diminished by running "enclosed" or in an atmosphere of carbon monoxide. The question is how much material is necessarily transported at a given current density, voltage and arc length and whether there is any law for arcs corresponding to Faraday's law for solutions. From the investigations of the author of the copper arc in air, the copper arc in hydrogen, the iron arc in hydrogen, and the carbon arc in hydrogen, it is quite evident that this is not the case. In some cases there is a tendency for the anode to gain in weight rather than lose, and the loss of material is very much smaller than would correspond to Faraday's law. With the copper arc in hydrogen and with water-cooled electrodes, there was transferred only about 1/1500 of the Faraday equivalent for solutions.

It seems that oxidation, or combination with the surrounding gas, is not absolutely necessary for the production of a luminous arc, but such combination facilitates its formation. With regard to the amount of material fed to the arc, there is apparently a tendency for the arc to ionize the surrounding atmosphere if there is not enough material vaporized from the electrode. If much heat is developed, more is vaporized than is employed in transporting the current. Between these two extremes, both the atmosphere and the electrode vapor are ionized. It is therefore hardly possible to make measurements which will give figures comparable to Faraday's equivalents. It appears that there is a slow gradation from the spark discharge to the true arc, passing through the intermediate stage where both kinds of discharge are present. The main distinction, therefore, between the arc and the spark discharge is that in the former vaporized material from the electrode or electrodes undergoes most of the ionization which takes place, while in the latter the surrounding atmosphere suffers most of the ionization.

The structure of metallic arcs in air is in general as follows: The very middle path is luminous, but the light is derived from the outer mantle and most frequently form that portion of the outer mantle next the inner path. In the carbon arc the outer mantle is not well defined, owing to the fact that the product of combustion is gaseous. It seems probable that the inner non-luminous path is in a way comparable to the Crookes dark space. The explanation given for the presence of the latter is that a large number of negative ions present have too great a velocity to ionize the atoms with which they collide, but that further along the tube, when their force has been diminished by collision, ionization may take place. Where this occurs, light is given off. In the arc the inner path may be caused by the fact that the negative ions, in very great number, are moving rapidly toward the anode and producing ionization only where the force has been sufficiently diminished by collision, viz., on the sides of the inner path.

From a number of experiments it appears that the cathode determines the character of the arc, but there are other instances which distinctly contradict such a general statement. The author gave some interesting notes on the explanation of the phenomena in the arc on the basis of the electron theory, but frankly stated that we are not yet enabled to give a complete and consistent theory. He finally stated that the character of the light is not determined simply by the heated particles present in the arc. There certainly may be heated particles present which are not active in giving off light. It does not appear altogether out of the question to associate the light derived from the cathode with negatively electrified particles, and that derived from the anode with positively electrified particles. There seems no necessity for making a more complicated assumption, although it must be admitted that one may be possible. It is perfectly conceivable, for instance, that under certain circumstances, the vapor from the anode may be ionized by negative ions, and consequently should be associated with the latter. The author's experiments with the magnetite-copper arc do not seem, however, to be in accord with this view.

In the discussion of Dr. Weedon's paper, Mr. E. E. F. Creighton referred to the influence of the wave form upon the voltaic arc, and exhibited several oscillograph curves. In his experiments he had a series of arc lamps operated at 2300 volts with 66 amperes, the wave form of the alternating arc being affected by the resistance, inductance, the length of the arc and the nature of the carbon. Mr. Hering thought, to get a strictly uniform current one should use the current from a storage battery. Dr. Weedon had used the current from a dynamo which is always somewhat fluctuating. Messrs. J. W. Richards, W. H. Browne also participated in the discussion.

COPPER VOLTAMETER.

Dr. ISAAC ADAMS and Prof. BARRY MACNUTT then presented a paper on some phenomena observed in connection with a copper voltameter which was read by Prof. MacNutt. In the course of a determination of the intensity of the horizontal component of the earth field by means of a tangent galvanometer the authors used a copper voltameter and observed some peculiar irregularities. When the reversals took place through the galvanometer they observed certain irregularities in the current which might be expressed as though polarization increased while the cell is open. Another point is the resolution of the deposited copper. Allowance must be made for both factors. The reversals should not be made too often, not oftener than say every five minutes, then the irregularities in the current are negligible; further, the amount of redissolved copper must be taken into account. If these precautions are taken, the copper voltameter is suitable for exact measurements. In the discussion, Mr. Hering remarked that in measurements requiring such a great accuracy (to the fourth decimal point) the copper voltameter should better not be used at all. Prof. MacNutt replied that if the proper precautions are taken, consistent results are obtained.

ELECTROLYTIC IRON.

A highly interesting paper by Prof. C. F. BURGESS and Mr. CARL HAMBUECHEN, of the University of Wisconsin, was then

presented. In the absence of the authors, it was read by Prof. J. W. Richards. While electric furnace processes have recently attracted much attention in their application to the metallurgy of iron and steel, it seems that the electrolytic effect has not been considered seriously, as it is commonly held that the difficulties inherent in the deposition of iron are such as to preclude its playing an important part in the industrial electrometallurgy of this element. The authors have, however, found that electrolytic iron can be produced in such quantities and at such cost as to make it a material of commercial as well as of scientific importance should sufficient demand for it arise.

A survey of available literature on the subject of electrolytic iron leads naturally to the assumption that its deposition is difficult to accomplish, and that there are few solutions from which it can be deposited. Moreover, it has been held that a satisfactory quality of deposit can be attained only by the use of very low current densities and an exceedingly slow rate of deposition. Practically the only uses to which electrolytic iron has been put are in the so-called "steel facing" of dies and electrotypes, and as a material for investigating the properties of the pure metal.

The hardness of electrolytic iron which makes it especially suited to the facing of electrotypes is due to the occluded hydrogen which is practically the only impurity present. In fact the very term "electrolytic iron" is commonly assumed to be synonymous with "pure iron." In just what manner the hydrogen is held by the metal is a matter of doubt, it being claimed by some that it is simply condensed, and by others that it forms a definite hydride. Such iron may contain this gas in quantities equal to several hundred times the volume of

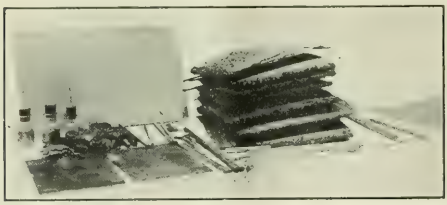


FIG. 3. ELECTROLYTIC IRON.

the metal, and it can be almost entirely freed from it by heating.

Something over two years ago the authors undertook an experimental investigation of the conditions suitable for electrolytically depositing iron, and this work has proceeded almost without interruption since that time. The primary object of the investigation was to produce, if possible, pure iron in such quantities and at such cost as to make it an available material for further inquiry into its properties. The preliminary work consisted in testing the various electrolyte materials which had been suggested previously, and from these the most promising were selected as the basis for further trials. A large number of iron salts were used and the effects of variations of density of solutions, current densities, temperature, agitation of electrolyte and various other factors were noted. As a result of such observations, ferrous sulphate, with a certain percentage of ammonium sulphate, was chosen as affording the most satisfactory results, and the process, as it is now being operated on a small experimental scale, is described as follows: The electrolyte consists of ferrous and ammonium sulphates; the current density at the cathode is 6 to 10 amperes per square foot of cathode surface, and at the anode slightly less; the e. m. f. for each cell is slightly under one volt; the temperature of electrolyte is about 30° C.; the anodes consist of ordinary grades of wrought iron and steel; the starting-sheets for the cathodes are of thin sheet-iron, previously cleaned of rust and steel.

One of the most serious difficulties encountered was in obtaining a thick deposit of iron. While there is a considerable range of conditions under which iron can be deposited uniformly and densely for a few hours, or perhaps for a few days, it was almost always found that the surface would become so rough or pitted, or that such a rapid treeing would take place, or that the deposit would curl up to such a degree that it was necessary to discontinue the experiment and start a new one under different conditions. But improvements have been gradually effected until at the present time it is possible to continue the run four weeks without replacing the cathodes. At the end of such time the cathode reaches an average thickness of about three-quarters of an inch, and the surface is so rough and nodular that it is not considered advisable to carry the deposition further.

The current efficiency of deposition is very closely 100 per cent; that is, there is a deposition of about one gram per ampere hour. The e. m. f. being one volt, gives about 2.2 pounds of iron per kilowatt-hour. Since all the factors which go to make up the cost of large scale production cannot be accurately determined from a small scale experiment, the authors are unable to state from the investigations what would be the cost of working on an industrial scale. For the past six months three tanks have been maintained in almost continuous operation, these tanks having the dimensions 8 inches wide x 13 inches long x 15 inches deep, and containing two anodes and one cathode. The finished cathodes from these tanks weigh about 20 pounds and constitute, perhaps, the largest pieces of electrolytic iron which have, up to the present time, been produced. The total amount of the material which has been produced from all experiments is about one-half ton.

A run of two months' duration was made to determine the extent of the deterioration of the electrolyte, resulting in the conclusion that the solution can be kept in good working condition with little trouble or expense. It would appear therefore that the cost of refining, aside from fixed charges on plant, and with power at $30 per kilowatt-year, would be under one-half cent per pound of iron, thus placing it not greatly in excess of the cost of refining copper.

Even with these figures realized, whether or not electrolytic iron can be profitably produced depends upon the uses which can be made of the refined metal. These in turn depend upon its properties, the most striking of which is its purity. Although the work was directed toward the production of electrolytic iron in a dense and massive condition, rather than in a high degree of purity, analyses which have been made show the purity to be in excess of 99.9 per cent. Not a trace of carbon was detected, and silicon, manganese and other impurities commonly found in iron appear to be absent. The only impurity which has been detected is hydrogen, which is present in appreciable quantities in the metal as taken from the electrolytic tanks. This gaseous element in its physical or chemical combination with iron influences, in a most striking manner, the physical properties of the metal. The hydrogen can be driven off almost completely, if not entirely, by heating to a white heat, the evolution commencing at a temperature below 100° C., and becoming rapid at a temperature below a red heat. Electrolytic iron heated in a Thomson welder or even in a Bunsen burner has been observed to give off hydrogen so rapidly that it ignites and continues to burn after removing the source of heat, presenting an appearance similar to that which would be produced by dipping the iron in alcohol and igniting it. The metal containing the hydrogen is so hard that it can be filed or sawed only with difficulty, and is so brittle that it is readily shattered by a sharp blow from a hammer. After the expulsion of the gas it becomes softer, and after having been raised to a welding temperature it assumes properties of malleability and toughness similar to those of Swedish iron.

The iron, when heated in a forge fire, can be readily welded and forged into any desired shape, and various test samples

were made in this way. During such working, however, impurities are introduced, analyses invariably showing the presence of a very small percentage of carbon. The cathodes, three-fourths of an inch in thickness, have a surface so rough that they cannot be rolled satisfactorily into sheets, though it is possible that improvements can yet be made in this respect which will enable smooth surfaces to be obtained. The deposit adheres so loosely to the starting sheets that it can be removed readily.

A considerable amount of work has been expended in the attempt to melt electrolytic iron without at the same time introducing impurities. The difficulties that lie in the way of doing this, however, are great on account of the high temperature necessary, and the affinity which the iron at such temperature has for many of the elements. The melting temperature of the pure iron seems to lie closely to that of platinum, though actual values have not as yet been determined from lack of suitable measuring instruments. Various forms of electric furnaces have been constructed for this purpose, a furnace of the inductor type appearing to be the most suitable for preventing the introduction of carbon. Results which have been somewhat satisfactory have been obtained by heating a molten electrolyte between graphite electrodes to a suitable temperature and introducing the metal into such molten bath. The metal thus produced is tough and malleable, while it also has a fracture of coarse crystalline nature. The affinity which the iron has for carbon is shown by the fact that it can be readily melted in a graphite crucible, while a silica crucible heated to a considerably higher degree melts before the iron in it begins to flow. The absorption of the carbon in the former case produces a fusible alloy of iron.

Experiments have shown that the hysteresis, permeability, and electrolytic resistance of electrolytic iron are greatly influenced by the amount of hydrogen in it. An iron ring was deposited in such form that a hysteresis and permeability loop could be determined by the Ewing method. It was found that by heating in boiling water the hysteresis was lowered several hundred per cent. By further heating in an oil bath to 200° the value was decreased still further, but to a smaller extent than in the first heating, and upon attempting to heat it to 500° the ring broke and the experiment was therefore interrupted. Certain samples of forged iron have shown permeability values equalling or even exceeding those of the highest permeability standard samples of Swedish iron. Other samples prepared under apparently identical conditions showed much poorer results, so that it is impossible as yet to draw definite conclusions as to the magnetic properties of electrolytic iron.

It having been shown that it is possible for electrolytic iron to be produced at a small cost, the question naturally rises as to what uses there may be for it. The first suggestion which naturally presents itself is that on account of its purity it would serve as a basis for investigating the properties of iron and its alloys. Investigations having for their object the determination of the influence of various elements alloyed with iron as regards its electrical properties have been unsatisfactory on account of the presence of other impurities which modify or mask the effect of the element which it is desired to study. Starting with the pure iron, therefore, alloys of a predetermined and definit composition can be produced, thus making such investigations of greater simplicity. Unless the difficulties encountered in the working of electrolytic iron on account of its roughness offer too serious an objection, it should compete favorably with the purer grades of commercial iron which are used for various purposes and which sell for three cents and upwards per pound.

Electrolytic iron naturally offers the means of manufacturing chemically pure iron compounds and for standardizing solutions in the analytical chemical laboratory. The electrolytic iron, in addition to its purity, has the advantage for the purpose just mentioned of rapidly dissolving in an acid solution. A test which was made to determine the rate at which electrolytic iron and iron wire sold as chemically pure for standardizing purposes dissolves, showed a ratio of one to twelve in favor of the former. By reason of the brittleness imparted by the occluded hydrogen, it can be readily broken up into grains of a desired size, and even reduced to a fine powder. Summing up their work thus far done, the authors say that it is possible to obtain electrolytic iron in large quantities, and at a reasonable cost, and that, therefore, iron should be added to the list of metals to which the process of electrolytic refining can be applied satisfactorily. Such iron possesses a high degree of purity, though just how closely it approaches absolute purity can be shown only by spectroscopic analyses or by other methods which have not yet been made use of.

In the discussion of the paper Mr. Woolsey McA. Johnson said that he made some small scale experiments concerning the electrolytic refining of iron and had used the same electrolyte as the authors, with an addition of an organic acid. The organic acid acts as a reservoir and always keeps the concentration of the hydrogen ions constant. To melt pure iron he suggests the following apparatus. Take Acheson graphite bars, six-inch diameter, machine out to crucible form and use pure Al_2O_3, mixed with water glass, specific gravity 1.10, brasquing. He advocated the usefulness of making experimental researches on a somewhat larger scale from the start, as has been done in this case by the authors. Mr. Carl Hering spoke of another problem, that of the reduction of iron from ores by electrolytic methods. In a preliminary investigation of this problem he has reached the result that this would be too expensive for two reasons. First, the number and area of tanks required for depositing as many tons of iron as are now produced by one of our large furnaces would be enormous. Secondly, the energy required would be large. In the blast furnace the heat of combustion of the reducing carbon is added to the process; a somewhat similar effect could, perhaps, be produced in electrolysis by using something like a depolarizer, but he did not think that there is any hope for industrial electrolytic reduction of iron from ores. He then asked why cast iron cannot be used for the anodes in the Burgess and Hambuechen refining process instead of wrought iron and steel, which are far more expensive. Messrs. Johnson and Richards thought that cast iron would be unsuitable on account of quick disintegration, so that the amount of anode scrap would be excessive.

The Reduction Temperature of Zinc Oxide.

A paper on this subject was presented by Mr. Woolsey McA. Johnson, of the Lanyon Zinc Co., who remarked that it is axiomatic to say that any determination which will give definitely any of the physical constants of a chemical reaction will be beneficial in working that reaction on a large metallurgical scale. In the reduction of zinc oxide by solid carbon, a reaction which absorbs considerable heat, a certain thermochemical potential must be reached before any chemical change takes place.

Before this point is reached the chemical potential of the reverse reaction is greater than that of the reduction. The difference of potential is a function of the difference of temperature between the "reaction temperature," and the temperature of the reacting bodies. If the function is a linear one, and we have the reduction temperature at 1050° C., the reaction velocity, when the reacting bodies are at 1100° C., will be five times as fast as the reaction velocity when the reacting bodies are 1060° C.

It is easy to say that to determine the reaction temperature, all that is necessary is to heat up the components of the reaction with a pyrometer in them and observe the temperature at which the reaction starts, but as anyone who has had any experience in the matter knows, it is found in practice that the lag of the reading in the pyrometer behind the reaction and the temperature gradient of the charge give often very discordant results.

A practical cell, to determine the reduction temperature of zinc oxide accurately and quickly, should conform to the following conditions. The cell should be made of a refractory material not reacting with the substance to be tested. The cell should be tight that the products of the reaction may escape through one small hole, so as to make a bright and sensitive flame. The cell should conduct heat to the charge and to the pyrometer so easily that the pyrometer junction and the charge are always at nearly the same temperature.

After some experimenting with fire-clay and fire-clay mixed with graphite, the substance which the author found to fill best these conditions was solid Acheson graphite bars, such as are suitable for the electrolysis of zinc chloride. These round bars make almost a perfect crucible if machined out on a lathe.

The cell which was finally adopted is described as follows: A four-inch round Acheson electrode is cut off in pieces four inches long. A two and one-half inch hole is drilled in this round bar on a lathe, its axis being the axis of the bar. A thread is cut in the top of the hole to receive the threaded cover, also made of graphite. In the lower part of the cell a three-fourths inch hole is drilled to receive the pyrometer, one-half inch of graphite being left between the charge and the pyrometer. All this work is done accurately by machine tools, for, as is well known, it is possible to machine Acheson graphite accurately. Just below the line of the charge a one-fourth inch or three-eighths inch hole is drilled. This hole is tapped to receive a threaded iron or graphite pipe, which is used in case the indicator is carbon monoxide gas and not zinc. When the zinc flame is used as an indicator, this pipe is not screwed into the hole.

In the experiments made by the author in connection with Mr. W. Chapman, the pyrometer used was the usual platinum-palladium platinum couple with the galvanometer reading directly in degrees Centigrade. A broken outside porcelain tube was used in preference to a new porcelain tube, because the radiation by the graphite on the junction gives very quickly the temperature of the cell to the pyrometer junction.

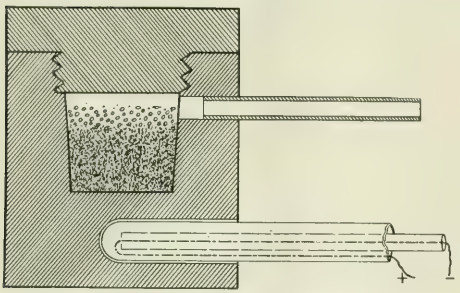


FIG. 4. APPARATUS FOR MEASURING THE REDUCTION TEMPERATURE.

The procedure in determining the reduction temperature is as follows: Equal parts of the material to be reduced are mixed with the reduction material filling the cavity to about one-half its height. A little of the coarse reducing material is sprinkled over the top. The cover is next screwed on, and the cell put in the furnace. The furnace is a specially built experimental reverberatory furnace, fired with natural gas and equipped with a heater for the air, and with checkerwork to make a quick combustion. A ten-inch graduated dial on the handle of the gas valve allows accurate adjustment of the flow of gas and a damper allows accurate adjustment of the flow of the air. By a proper regulation of the temperature and flow of air and flow of gas it is possible to have a radiant flame consisting of hot particles of carbon of almost any temperature from 900° to 1700° C. This radiant flame heats the cell without undue oxidation of the graphite. The degree of regulation can be seen in the curve of experiment No. 10, where in the second determination the temperature increased as a linear function of the time by 30° in 30 minutes.

The pyrometer is next inserted into the cell and clamped to a wrought iron support outside the furnace. It is then connected to a permanent circuit leading to the galvanometer. The galvanometer is placed on a pier made of bricks, laid in cement about 6 feet from the furnace. The door of the furnace is partially closed with a block of fire-brick.

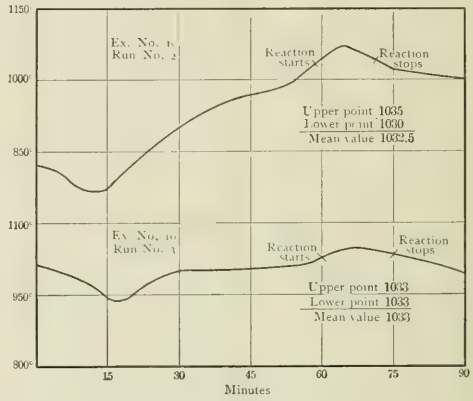


FIG. 5. DETERMINATION OF REDUCTION TEMPERATURES.

The temperature is first raised quickly and a rough determination made of the temperature at which the snakey flame is given off. The cell is cooled down and the temperature at which the zinc ceases to be given off is taken. The mean of these two values is then 10° to 15° off the true value. The last one is usually fairly close to the final value. Now the gas is turned on again and the temperature of the cell raised very slightly at the suspected temperature. While one observer reads the pyrometer and regulates the gas the other watches the small hole in the cell for the zinc flame. When the reaction starts the observer reading the pyrometer is notified and the point where the reaction starts is marked down on the curve which is plotted during the determination. The temperature of the cell is raised 5° or 10° to insure this is the real reaction and not a chance reaction due to impurities in the mixture. If the reaction is the real reaction and not a false reaction, the evolution of zinc and carbon monoxide increases rapidly with the temperature. The temperature is then lowered slightly and the point at which the reaction stops is noted down. Two or three determinations are made and the mean of the means taken as the true value. The means usually agree within 2° or 3° with each other. If the values are not concordant the reason is to be found in an inhomogeneous charge. Thus in one experiment the preliminary value was found to be 1020° C. The author accordingly raised on the first determination the temperature quite rapidly to 1020° C. and then slowly. The reaction started at 1035° and stopped at 1030° C., giving as a mean 1032.5° C. On the second trial the reaction started at 1033° C., and stopped at 1033° C., giving a mean of 1033° C. and a mean of means also of 1033° C. They have made even closer determinations than these, but of course this would be due to chance, and the above is a little bit better than the average.

A glance at Table I. brings out quite clearly what has been the somewhat indefinite opinion of zinc smelters from practical observation, namely, that the temperature of roasting effects the ease of reduction, and that different reducing materials have different rates of reduction. The idea of the

author is that the reduction of zinc oxide is caused by the very slight vapor of solid carbon and the slight dissociation pressure of zinc oxide tending to break up the zinc oxide into zinc and free oxygen. It is easy to imagine the effect of heat in making a denser and more stable configuration of the atoms in the molecule on reducing these vapor pressures. It can even

TABLE I.—REACTION TEMPERATURES.

Material to be Reduced.	Reducing Material.	Corrected Mean of Means.
C. P. zinc oxide	1100° charcoal	1022° C.
C. P. zinc oxide, calcined at 1300° C	"	1025
C. P. zinc oxide	Soft coke	1029
C. P. zinc oxide calcined at 1100° C	"	1048
C. P. zinc oxide, calcined at 1300° C	"	1061
C. P. zinc oxide	Graphite turning	1084
Roasted Colorado ore	Soft coke	1029
Roasted Joplin ore	"	1073
Roasted Joplin ore	Very soft, 600° charcoal	1033
Roasted Joplin ore	1100° charcoal	1059
Roasted Colorado ore	1500° charcoal	1073
Joplin ore	"	1087
Joplin ore	Graphite turning	1116
Colorado ore	"	1120
B. P. Cadmium	"	756
C. P. Cadmium oxide, made by wet method	600° charcoal	767
C. P. Cadmium oxide, made by wet method	1100° coke	813
C. P. Cadmium oxide, made by wet method	Graphite turning	849
Zinc Sulfid, from Joplin	Cast iron filings	1187

Same coke used in all experiments made in 48 hours in bee-hive ovens. 87 per cent fixed carbon; 1 per cent volatile.
Joplin ore from bin roasted at about 1050 degs. C.
Colorado ore from bin roasted at 900 to 950 degs. C.
Charcoal was made by heating Southern pine in large covered crucible, until volatile matter ceased evolving.

be conceived how the change is an electrochemical one in its nature, and that the electrons play a very material roll. These results and conceptions tend to show that the primary reduction of zinc oxide by carbon is not caused by carbon monoxide, although there is no doubt that carbon monoxide does tend to increase the rate of reduction after the primary reduction is once started. The above, however, is more an opinion gained by intuition from seeing many experiments on the reduction of zinc rather than any rigid deduction from the experiments.

In the discussion which followed the reading of Mr. Johnson's paper, Mr. G. L. Cabot asked whether experiments had been made on the reduction of zinc oxide by the direct action of natural gas. Mr. Johnson replied that while several attempts had ben made in this direction by various experimenters, satisfactory results have not yet been obtained. Dr. J. W. Richards expressed himself in favor of Mr. Johnson's hypothesis that the carbon vapor plays a very important part in the reduction and referred to the analogous process of reducing silicon. Mr. C. J. Reed thought that carbon vapor does not exist at temperatures such as those used in the experiments as otherwise the manufacture of an incandescent lamp would be impossible. Mr. Johnson replied that only a very small amount of carbon vapor needs to be assumed, and that the blackening of the globe of an incandescent lamp proves the existence of carbon vapor, but Mr. Cabot suggested that this was rather an effect of the current than of the heat. Mr. Johnson pointed out what a fine material Acheson graphite is and that nearly everything may be made from it. He proposed the use of an apparatus like that used in his experiments, for distilling cadmium for its employment as a material in standard cells.

MISCELLANEOUS.

Mr. S. S. Sadtler, the newly-elected secretary, then showed some samples of porous diaphragms which may be ground down to any convenient thickness, so that their resistance is very small. They may be made up in any form useful for experimental or commercial purposes. We intend to refer to the same in a future issue.

Mr. C. J. Reed, the retiring secretary, read a letter from Dr. W. D. Bancroft, calling the attention of the Society to the "Relative Decimal Card Index for Electrochemical Interests" of Mr. L. VOEGE in Zurich, Switzerland. The co-operation of the members of the society was requested. A paper by Mr. Voege on this subject had been sent, but was not read at the meeting on account of limitations of time. After its publication in the Transactions of the Society, it will be noticed in these columns.

The following three papers were read by title, but not discussed at the meeting. Advance sheets, however, were distributed from which the following abstracts have been prepared.

ELECTROLYTIC PREPARATION OF WHITE LEAD.

A paper by Mr. C. F. CARRIER, JR., gives an account of some laboratory observations on the electrolytic preparation of white lead. The original patents of Luckow specified that a 1½ per cent solution of a mixture of 90 parts $NaClO_3$ and 10 parts Na_2CO_3 should be electrolyzed between a hard-lead cathode and a soft-lead anode, CO_2, and water being added as required. It was shown, however, by LeBlanc and Bindschedler, and Isenburg, that true white lead could only be produced when the CO_2 is greatly diluted with air. The most satisfactory proportion was found to be 1 part CO_2 to about 20 parts of air. In this case, however, the absorption of the CO_2 by the electrolyte is by no means complete, and provision for reuse must be made, or great loss will ensue. The question now arose as to whether basic lead carbonate of the desired composition could be produced by some process differing essentially from that of Luckow.

As the subject of the experiments of the author the process of Richard and Roepper (U. S. P. 644,779) was chosen. It consists in electrolyzing a 5 per cent solution of a mixture of 1 part Na_2SO_3 and 40 parts CH_3COONa with lead electrodes, a small quantity of some nitrate being added to aid the solution of the anode. With a current density of 100 to 200 ampere per m^2, the acetic acid anions are supposed to be decomposed at the anode, yielding CO_2 to precipitate the white lead, the necessary admixture of hydroxide being formed by action of the sulphite.

The author describes a series of experiments which he has made under different conditions and some of the main results of his observations are as follows. The use of copper cathodes reduces the voltage between the cell terminals. With a current density of 100 amperes, or more, per m^2, the anode dissolves irregularly, "pitting" badly. With a solution containing enough hydroxide to precipitate white lead, spongy lead is deposited on the cathode, even in those experiments in which the product was largely carbonate. To prevent a large deposit of lead on the cathode, it would seem necessary to have a permanent store of CO_3 ions in the solution, thus making Na_2CO_3 or other soluble carbonate an essential constituent of the electrolyte. The solution effect of nitrates on lead, when added to the acetate solution, seems to have a higher efficiency than chlorate alone. The tendency of lead to deposit on the cathode is less with a more dilute solution. To procure basic carbonate of the proper composition requires a fineness of regulation of CO_2 dilution beyond the command of the apparatus which were at the author's disposition.

OSMOTIC PRESSURE AND ALTERNATING CURRENT.

A paper by Mr. WILLIAM H. DAVIS records some peculiar observations made in the course of experiments to perfect a method of recovery of cyanogen from the double salts of a cyanide solution. A direct current was first used, but it was soon found that a division of the compound sought (KCN) was the result, and that correction could not be made by placing the anode in a porous cup, for the alkali and acid radicles were constantly being separated by the current effect. Therefore, if a solution of alkali, say caustic soda, was contained in the porous cup, the sodium radical would pass out proportional to the entering cyanogen, and if an excess of caustic soda was maintained, even by washing the anode, a poly-

merization of the cyanogen would occur in sufficient amount to make the process valueless for the work at hand.

Experiments were then made with alternating current, and it was found that the desired results were obtained together with precipitation of the basic metals when an excess of free alkali was present. The determinations were made by the usual Lebig method ($AgNO_3$) and it was found that by no other method could the cyanide content be raised higher. In the case of foul solutions the cyanide was in many cases raised 0.5 of one per cent. The author refers to the report of the director of the Mint on the production of precious metals in the United States in 1903, pages 99 to 101.

The author then studied the theoretical side of the problem and found that "an alternating current would raise the osmotic pressure of a solution concentrated so that complete dissociation was not present."

The experiment is described as follows: A porous cup holding about 200 cc. was rendered semi-permeable with copper-ferrocyanide and the walls so adjusted that the cup would maintain a hydrostatic pressure of one cm. above the water level outside the cup. A rubber stopper with two holes was then placed securely in the cup, through one of which holes a glass tube was inserted, one square mm. in cross-section, reaching within 1 mm. of the bottom of the cup, and through the other hole another tube was inserted reaching only to the bottom of the stopper; the hole was then sealed with sealing wax and placed in a beaker of distilled water, wires of platinum were placed in the tubes, which served as electrodes, and these were connected to a switchboard. Through the tube reaching to the bottom of the cup a 10 per cent solution of sodium-acetate was led into the cup until the height in the tubes indicated 10 cm. above the water level outside the cup, and then the apparatus was allowed to stand for twenty-four hours. At the end of this time the solution stood 1 cm. above the water level, and then 2 amperes of alternating current were sent through the solution. No changes were made excepting to close the switch. In five seconds the solution rose to 5 cm. and would not go higher during the next thirty seconds. The current was then turned off and the solution fell to the initial height in about twenty minutes. The current was again turned on and the same results followed, and this was gone through with perhaps twenty times during the week or ten days following. The current was from a three-phase generator of the usual type, working at sixty cycles per second; one leg of the circuit was used and the current was controlled by a bank of incandescent lamps connected in multiple.

Manufacture of Ferro-Nickel from Pyrrhotite.

A paper by Mr. Ernst A. Sjöstedt, chief metallurgist of the Consolidated Lake Superior Power Co., gives an account of electric smelting experiments made at Sault Ste. Marie for the manufacture of ferro-nickel from pyrrhotite. An account of his process, and an illustrated description of his furnace have already been given in our April number, page 153 and 154, to which the reader may be referred.* The present paper of the author contains some supplementary information. The furnace lining is made of magnesia brick, the only material which he has found to withstand the heat and chemical action between the charge and the lining. These bricks have the following composition:

SiO_2	4.41 per cent
Al_2O_3	23.07 "
CaO	9.40 "
MgO	63.12 "

He gives the following estimate of cost for a furnace of 300 to 500 hp., in which 200 hp. would probably suffice for obtaining a gross ton of ferro-nickel per twenty-four hours. At a rate of $10.00 per hp.-year for power, $5.00 per ton for the ore, $5.50 per ton for coke, and $2.50 per ton for limestone, the cost items for the manufacture of 1 ton of ferro-nickel pig in the electric furnace at this place would probably have been as follows:

2 tons partly roasted pyrrhotite at $5	$10.00
500 pounds coke, at $5.50	1.37
1.5 ton limestone fines, at $3.00	4.50
Labor and salaries	2.50
Electrodes and repairs	2.50
Power, 200 hp., at $10.00	5.50
Total cost per ton metal	$26.37

The value of this product—a ferro-nickel pig with 3 per cent nickel contents—should be that of the nickel contained in the metal plus that of the pig iron; so that, if we assume the value of nickel at 30 cents per pound, and pig iron at $14.00 per ton, the product would be worth ($60 \times \$.30 = \$18.00 + \$13.57$ or) $31.57—showing a profit of over $5.00 per ton of metal produced.

In the following we give an alphabetical list of all members and guests who registered at the meeting:

Lawrence Addicks, Perth Amboy, N. J.; Sydney W. Ashe, New York; C. Baskerville, Chapel Hill, N. C.; F. M. Becket, Niagara Falls, N. Y.; Philander Betts, Washington, D. C.; Mrs. S. S. Birdsell, Boston, Mass.; Henry S. Blackmore, Mount Vernon, N. Y.; H. B. Brooks, Washington, D. C.; William Hand Browne, Jr., New York; E. A. Byrnes, Washington, D. C.; Mrs. E. A. Byrnes, Washington, D. D.; G. L. Cabot, Boston, Mass.; H. S. Carhart, Ann Arbor, Mich.; C. R. Cary, Baltimore, Md.; G. B. Chorpening, Clarksburg, W. Va.; George B. Cock, Philadelphia, Pa.; E. E. F. Creighton, Pittsfield, Mass.; Mrs. C. H. Cromwell, Savannah, Ga.; F. P. Dewey, Lanier Heights, Washington, D. C.; William Dreyfus, New York; C. W. Fairbank, Washington, D. C.; F. A. J. Fitzgerald, Niagara Falls, N. Y.; S. P. Franchot, Niagara Falls, N. Y.; R. Gahl, Philadelphia, Pa.; Mrs. R. Gahl, Philadelphia, Pa.; F. W. Grover, Washington, D. C.; Karl E. Guthe, Washington, D. C.; Aaron Hale, Boston, Mass.; Carl Hering, Philadelphia, Pa.; F. W. Higgins, Niagara Falls, N. Y.; B. H. Hite, Morgantown, W. Va.; H. L. Hodgkins, Washington, D. C.; F. A. Holton, Washington, D. C.; N. M. Hopkins, Washington, D. C.; William Smith Horry, Niagara Falls, N. Y.; Mrs. W. S. Horry, New York; E. J. Hutchinson, Cincinnati, O.; H. W. Jenkins, New Orleans, La.; W. McA. Johnson, Iola, Kan.; Edward Keller, Baltimore, Md.; E. B. LeMare, Lathkil, Rusholme, Manchester, Eng.; M. G. Lloyd, Washington, D. C.; H. J. Lucke, Washington, D. C.; Mrs. H. J. Lucke, Washington, D. C.; Barry MacNutt, Bethlehem, Pa.; A. B. Marvin, Jr., Washington, D. C.; H. T. Matthew, New York; G. E. Middleton, Washington, D. C.; Jefferson Middleton, Washington, D. C.; Mrs. J. Middleton, Washington, D. C.; Mrs. William B. Moncine, Washington, D. C.; W. R. Mott, Ithaca, N. Y.; E. H. Mullin, New York; C M. Nissen, Washington, D. C.; William A. Noyes, Baltimore, Md.; R. J. Nunn, Savannah, Ga.; Raymond Outwater, Washington, D. C.; Henry Noel Potter, New York; E. J. Prindle, Washington, D. C.; Samuel Reber, Washington, D. C.; C. J. Reed, Philadelphia, Pa.; Clarence E. Reid, Washington, D. C.; J. W. Richards, Bethlehem, Pa.; Mrs. J. W. Richards, Bethlehem, Pa.; William Richards, Bethlehem, Pa.; A. G. Rodgers, Niagara Falls, N. Y.; E. F. Roeber, New York; S. S. Sadtler, Philadelphia, Pa.; G. E. Schmitt, New York; G. P. Scholl, Philadelphia, Pa.; Mrs. Johanna Abels Scholl, Philadelphia, Pa.; A. W. Smith, Cleveland, O.; W. O. Snelling, Washington, D. C.; H. Stokes, Penn Yan, N. Y.; E. Stütz, New York; E. R. Taylor, Penn Yan, N. Y.; Mrs. E. R. Taylor, Penn Yan, N. Y.; C. P. Townsend, Washington, D. C.; Mrs. C. P. Townsend, Washington, D. C.; G. L. Townsend, Washington, D. C.; Miss Sue R. Truestall, Washington, D. C.; F. von Kügelgen, Holcomb Rock, Va.; C. D. Vreeland, Upper Montclair; Charles W. Waidner, Washington, D. C.; William S. Weedon, Schenectady, N. Y.; Mrs. William S. Weedon, Schenectady, N. Y.; H. W. Wiley, Washington, D. C.; Frank A. Wolff, Jr., Washington, D. C.; Charles C. Wright, Washington, D. C.

The Electric Furnace in Metallurgy.—An interesting lecture on this subject was recently delivered by M. R. Petaval, of Paris, at the Chemical Institute of Nancy. It has been published as a bulletin of the Société Industrielle de l' Est. The author emphasizes that the electric furnace is no longer to be considered as a commercial possibility, but as an accomplished fact, and gives some data on commercial plants in which electric furnaces are used in connection with steel, zinc, nickel, ferro-silicon and ferro-chromium. The largest part of the lecture deals with steel processes and some suggestions are quite interesting. We will abstract it in our next issue.

*See also the letter in the correspondence columns of our present issue.

ELECTROCHEMISTRY AT THE UNIVERSITY OF WISCONSIN.*

By Prof. Charles F. Burgess.

While the birth of electrochemistry antedates that of the other branches of electrical engineering, it is only within comparatively recent years that its importance has increased to such a degree that special courses of study devoted particularly to this branch of science and technology have been introduced in our universities and technical school. The renewed interest in electrical phenomena in their relation to chemical phenomena has resulted in and has been further promoted by notable scientific discoveries, the introduction of new theories, the establishment of a new school of physical chemistry, and in many profitable technical applications of electricity to the production of elements and compounds some of which had been unknown hitherto.

Though electrochemistry has had its main growth within the past two decades; its development has been so rapid that it now constitutes an acknowledged branch of engineering, which, by requiring men of special training, has led to the introduction of new courses of study in some of study in some of the engineering colleges.

The University of Wisconsin was among the first in this country to take up this line of work, an electrochemical course of three hours per week for one term having been given by the Electrical Engineering Department in 1894. Shortly thereafter the facilities were notably increased through the establishment by Dr. Louis Kahlenberg of a course in physical chemistry, dealing with the modern views of the German school of electrochemists, which his studies in Europe made him most qualified to teach.

Three years ago a four years' course of study in applied electrochemistry was added to the various courses offered by the College of Engineering, and the interest which has been shown by the students and the growing demand for the graduates show that this addition was fully warranted. It is the purpose of this course to afford a training in the fundamental principles of physics, chemistry and engineering, such as may fit its graduates for entering industrial pursuits in chemical, mechanical, electrical and electrochemical engineering where a co-ordination of chemistry with the more strictly engineering branches is necessary.

The course in applied electrochemistry as here given is co-ordinate with the electrical engineering course, differing from it mainly in including a considerable proportion of chemical work throughout the four years. Such chemical work includes courses in general chemistry, analytical, organic, physical chemistry and electrochemistry.

FIG. 1.—ELECTROLYTIC TANKS.

The work for the first year includes German or French, English, algebra, descriptive geometry, trigonometry, analytical geometry, mechanical drawing, shop work and general chemistry.

For the second year technical German or French, analytical and descriptive geometry, calculus, physics, kinematics, mechanics, shop work and analytical chemistry are required.

The list for the third year includes mechanics, precision of measurements, applied electromagnetism, materials of construction, advanced analytical chemistry and assaying, chemical preparations, physical chemistry and electives.

For the senior year the studies are alternating currents, steam engineering, testing of materials of construction, electrical installations, electric lighting and power transmission,

*At the request of the editor of the Electrochemical Industry this description of the work and equipment in electrochemistry at the University of Wisconsin has been submitted in the belief that what our universities are doing for the promotion of electrochemistry may be of interest as representing a certain phase of electrochemical work in this country.

contracts, chemical machinery, organic chemistry, applied electrochemistry, thesis and electives.

The junior work in physical chemistry deals with the fundamental principles and modern theories of electrochemistry and includes laboratory practice in the making of various measurements and determinations.

The course in chemical preparations and industrial chemistry is designed with the view to impressing upon the student the matter of costs. It is almost entirely a laboratory course and each student makes on a fairly good scale various typical chemical products. He is required to give a statement of the efficiency of the process, materials consumed, materials produced, waste products, methods of procedure on a large scale, the machinery and apparatus necessary, and an estimate of labor and power. In this manner it is sought to impress the economic questions which enter into chemical work.

LOUIS KAHLENBERG.

The study of chemical machinery is a classroom course dealing with the various machines and appliances used in chemical industries together with a consideration of various processes, such as drying, evaporation, distillation, etc.

The work in applied electrochemistry consists of class work, supplemented by laboratory exercises relating to the application of the laws and principles of electrochemistry as applied to various industrial purposes, including the deposition of metals in plating, electrotyping and refining, primary and secondary batteries, and the various electrochemical products and processes which have become of technical importance.

The course of study here outlined has certain limitations which it is the purpose to overcome in the future as rapidly as facilities may permit. One of the most serious difficulties in designing a course in applied electrochemistry is the necessity of crowding into four years all the studies which seem essential and desirable to satisfactorily equip the graduate for entering professional work. For best results, therefore, it seems desirable to extend the work one or two years above the regulation four years. It is the purpose to leave the election of a certain proportion of the work to the individual students' preferences, and among the electives from which choice may be made to advantage are the following studies given in various departments of the university: Mineralogy, geology, assaying, electrolysis and electrosynthesis of organic compounds, courses in physical chemistry, thermal chemistry, electrical testing, electricity in mining and quarrying, central station design, management and estimates, photometry, hydraulics, gas engines, compressed air, and masonry construction.

Laboratory work plays an important part in the teaching of many of the courses, and this together with the thesis work, upon which considerable stress is laid, develops the thinking powers and the abilities of independent observation and investigation.

Two parties of students and instructors are organized each year to go upon inspection trips on which visits are made to manufacturing plants and large engineering enterprises of the various industrial centers. Each student is expected to accompany two of these parties during the last two years of his course.

At the physical chemistry seminary which holds a meeting one evening each week, and which is attended by the advanced and graduate students who elect to take part, original articles of importance appearing in the scientific publications are reported upon and studied in detail.

The local section of the American Institute of Electrical Engineers, which holds frequent meetings and takes up the papers presented before the general society enables the students to follow electrical developments, and electrochemical matters are discussed in similar meetings of the local section of the American Electrochemical Society.

Physical Chemistry Laboratory.

The work in physical chemistry is under the direction of Dr. Louis Kahlenberg, assisted by Mr. F. L. Shinn. The physical chemistry laboratory occupies the basement of the present chemical building, the size of which is about 50 feet x 150 feet. The construction of a large new chemical building, which is shortly to be begun, will greatly increase the laboratory space devoted to this work. The present space includes one large general laboratory which will accommodate about thirty students. A balance room and two dark rooms are connected to this general laboratory. Another room, which is supplied with current from a series of storage cells and a 110-volt dynamo is devoted exclusively to electrolytic work. The equipment consists of ampere meters and voltmeters, potentiometers, electrometers, carefully calibrated resistances, etc., which may be required for special work. The department owns a complete outfit for the measurement of dielectric constants, including Nernst's apparatus, and that of Drude in their latest forms.

Three other laboratories are devoted to research work, and are equipped with chemical tables, hoods, water, gas and electricity and otherwise equipped for handling various classes of work, as occasion may require.

The laboratory owns a Pulfrich refractometer of the latest pattern, with all accessories, also spectroscopes, polariscopes, chemometers, and apparatus for measuring critical pressures and volumes. A very complete set of thermometers of various kinds, calorimeters for the determination of specific heats, latent heats and heats of chemical reaction are available as well as the ordinary apparatus for measuring electrical conductivities, differences of potential, balances, thermostats, etc., which are necessary for physical chemistry work.

CHARLES F. BURGESS.

To provide for the extensive researches undertaken in the field of non-aqueous solutions there is a large collection of all typical solvents of organic and inorganic character.

The general students in physical chemistry take all the work outlined in a laboratory manual, such as that of Ostwald-Luther. In electrochemistry the work includes the determination of electrical conductivities of single potentials and of potentials of various galvanic chains, decomposition points, verification of Faraday's law, influence of the e. m. f., current density, temperature and chemical nature of the electrolyte upon the character of electrolytic deposits. The determination of dielectric constants, and the preparation of typical chemical substances by electrolysis also constitutes part of the work. Instruction is also given in the testing and opera-

tion of batteries, and construction of standard cells and normal electrodes.

For thesis and advanced work, special lines of investigation are pursued, such being determined by the purpose of the student and the facilities afforded by the laboratory. Funds are available for obtaining additional apparatus needed for special work which may be in progress.

At the present time the lines of investigation upon which work is being done include vapor tensions, osmosis, decomposition potentials, e. m. f. of galvanic chains in solvents other than water, thermal changes accompanying chemical reactions which take place in non-aqueous solvents, and measurements of dielectric constants and chemical equilibrium.

On the conductivity of a large number of non-aqueous solutions in various solvents, prominent among which is a research on the conductivity of solutions in liquid hydrocyanic acid.

The toxic action of various solutions and of metals upon plants and animals, and the taste of aqueous solutions were investigated.

All of these various investigations had for their special object the inquiry into the nature of solutions, and were primarily undertaken to verify present theories of solutions, and the theory of electrolytic dissociation. As these researches progressed, however, it became evident from the facts established that our present theories are inadequate. Ralizing this

FIG. 2.—APPLIED ELECTROCHEMISTRY LABORATORY.

A. Lecture Room, with projection lantern. B. Workshop. C. Office and Analytical Room. D. Electrodepositing Room. 1. Storage Batteries. 2. Electrolytic Vats. 3. Cleaning Tanks. 4. Motor-Generator. 5. Switchboard. 6. Centrifugal Separator. 7. Rotary Ball Mill. 8. Compressed Air Receiver. E. Grinding and Polishing Room. F. Drying Room. G. Store Room. H. General Electrolytic Laboratory. 1. General Switchboard. 2. Work Tables. 3. Hood. 4. Reagent Stand. 5-6. Instrument Cases. 7. Filter Press. 8. Electrolytic Bench. I. Electric Furnace Room. J. Storage Battery Room. K, L, M. Research Rooms. N. General Laboratory.

Investigations of the past few years which have yielded results of interest and importance include the following:

Dielectric constants of solvents and solutions.

Potentials of galvanic cells containing solvents other than water.

Electrolysis in non-aqueous solutions and the validity of Faraday's law in such solutions.

Instantaneous chemical reactions in non-aqueous, non-conducting solutions.

Specific and latent heats of evaporation, and on a new method of determining the same.

On the relation between boiling points and freezing points and electrical conductivity in aqueous and non-aqueous solutions, especially as viewed in the light of the theory of electrolytic dissociation.

fact, further researches are being conducted with the express purpose of placing our theoretical notions of solutions, osmosis, and electrical conduction upon a better and more rational basis.

Applied Electrochemistry Laboratory.

The work in applied electrochemistry is under the direction of Prof. C. F. Burgess, assisted by Mr. Carl Hambuechen and Mr. J. G. Zimmerman. The laboratory occupies the second floor of the electrical laboratories, the plan being shown in the accompanying drawing. The portion of the floor which includes the research rooms is at present in process of construction, and will practically double the space available for electrochemical work.

The present space includes a large plating room, rooms for polishing and grinding, chemical analysis and weighing, work

shop, drying room, general laboratory, high-tension room, research laboratories, a storage battery room, and store rooms, one of which is not shown on the plan. On the first floor adjoining the dynamo room is the electric furnace laboratory.

The plating room equipment comprises a motor-generator having a capacity of 300 amperes at a pressure up to 10 volts on the low pressure side; twelve large lead lined, wood and enamel lined tanks of a capacity of from 30 to 60 gallons capacity, hot water, lye and cleaning tanks. Plating and refining solutions for copper, nickel and zinc are maintained continually, and the other tanks are used for experimental work on various other solutions. A rheostat is connected to each tank, and voltmeters and ampere meters are installed so that by a simple switching arrangement they may be connected to any of the tank terminals. The equipment in the electrodepositing department was obtained chiefly from the Hanson & Van Winkle Co., and is similar to that installed by them in technical plants.

The grinding and polishing room contains two high-speed lathes, driven by an electric motor. By means of the above equipment instruction is given in electroplating, electrotyping, and the refining and recovery of metals.

The equipment of the general laboratory includes eight specially designed switchboards for varying and regulating the current used in small electrolytic experiments, together with a large number of rheostats, electrolytic tanks, stirring devices, instruments for measuring current, e. m. f. and resistance. A considerable proportion of the apparatus has been designed and constructed in the laboratory, and to the valuable assistance of the Mechanism department of the College of Engineering, in charge of Mr. E. H. J. Lorenz, many of the special instruments and devices are due. The equipment also includes balances, filter presses, centrifugal drying machine, a rotary ball mill and other grinding mills, a vacuum drying oven, etc. A system of compressed air furnishes at various outlets around the laboratory air at a pressure of 60 pounds to the square inch.

Electrical energy is furnished by the dynamo laboratory and by the city lighting and power circuits. Both alternating and direct currents are available, the former in quantities up to several hundred amperes at a pressure of 110 volts, and the latter up to 1000 amperes at the same pressure. By means of a 20-kw. high-tension transformer, pressures are available in values up to 60,000 volts.

In the electric furnace room is a switchboard connected to a Bullock direct-current generator, capable of delivering 1000 amperes at a pressure of 110 volts. This current is regulated and controlled for furnace work by a water-pipe rheostat illustrated in accompanying photograph. It consists of ten lengths of ¼-inch wrought iron pipe capable of carrying about 250 amperes without excessive heating with no water circulating, and a maximum capacity considerably above 1000 amperes with the water turned on. The current is regulated in ten steps by opening or closing the switches, which short-circuit the various sections as may be required. A self-acting switch protects the generator and engine from damage by sudden short-circuits. Water is supplied to each of the lengths of pipe through a two-foot length of rubber hose, such material being necessary to prevent short circuits between the consecutive lengths of pipe.

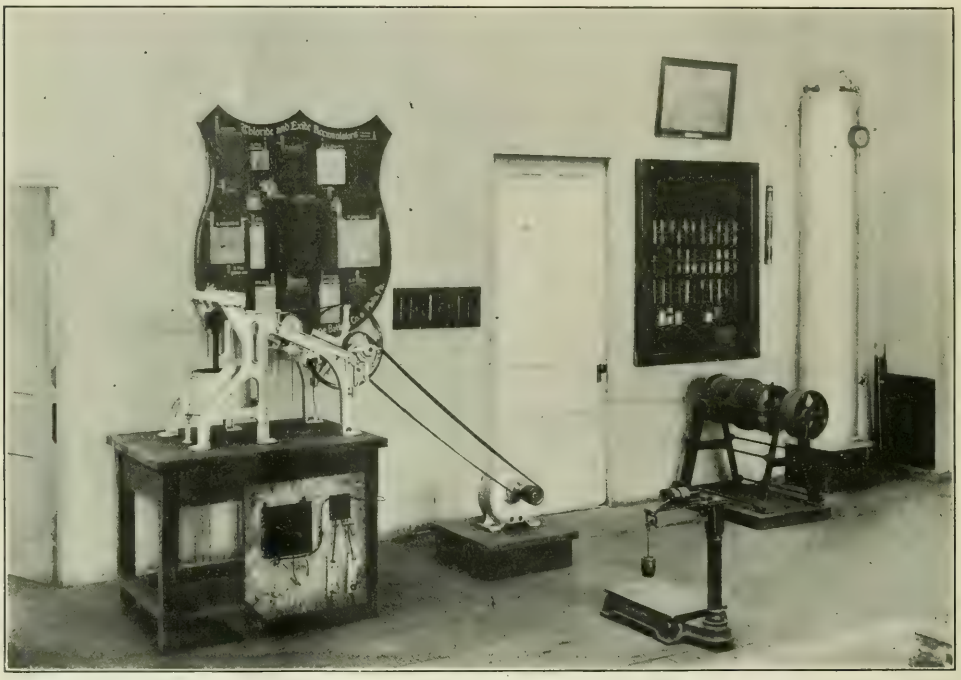


FIG. 3. CENTRIFUGAL SEPARATOR AND GRINDING MILL.

A 10-kw. auxiliary rheostat made by the Wirt Electric Co., of Philadelphia, consisting of cast-iron strips supported on an iron frame and mounted on rollers serves for handling currents below 150 amperes.

Alternating current for high temperature work is obtained from alternators in the electrical laboratory and from the city power circuit and is at present available in quantities up

to 40 kw., although a 200 kw. alternator is to be installed, and in operation within a few months. For adapting the alternating pressures to the various uses required in furnace work a 20-kw. transformer was specially designed for this purpose and constructed in the laboratory. By means of switching arrangements it may receive its full capacity at pressures ranging from 110 to 220 volts, and the switches which connect the subdivided secondaries in series or parallel pressures

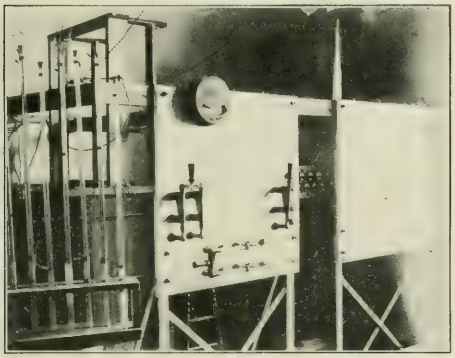


FIG. 4. 50,000-VOLT TRANSFORMER AND SWITCHBOARD.

from 15 to 200 volts may be delivered to the furnaces. A high-pressure coil, capable of delivering 20 amperes at 1000 volts is used for operating high resistance electric furnaces where the material under treatment is a high resistance substance such as molten silica.

Various small electric furnaces of the Moissan and Borchers types which have been imported are installed and used for various high temperature small scale experiments. Most

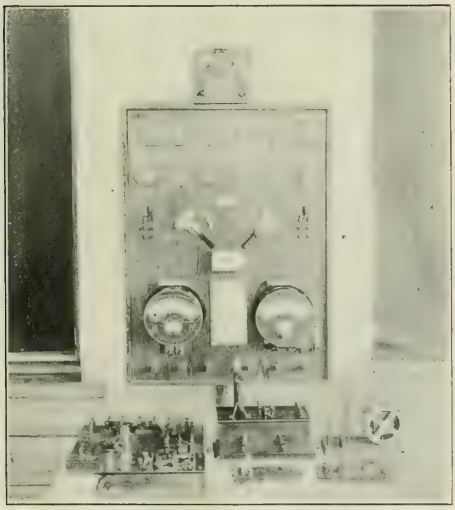


FIG. 5.—INSTRUMENTS MADE IN LABORATORY.

of the furnaces used have been, however, constructed in the laboratory, various refractory materials, such as magnesite and silica fire-bricks, magnesia, lime, silica, etc., being employed in such construction.

To adapt the electrode supports to the construction of various types of furnaces necessary for a variety of experimental work, two sets of electrode supports have been designed and constructed, and which have given excellent satisfaction. These are capable of holding carbon or graphite rods up to 2 inches in diameter, and have a capacity for handling currents up to 1000 amperes, the terminal blocks being provided

FIG. 6.—ELECTROLYTIC WORK TABLES.

with water-cooling pipes. The horizontal type is capable of vertical adjustment by means of a slot and lock-nut and the electrodes may be set at any desired angle through 90°. The electrodes are adjustable backward and forward by means of lever arms. The vertical electrode supports are an adaptation inches of the vertical type suggested by Mr. R. S. Hutton, of Owens College, Manchester, England.

The work tables of the furnace room are constructed of wood frames supporting a top of concrete and cement three inches thick. This form of top was adopted to reduce dan-

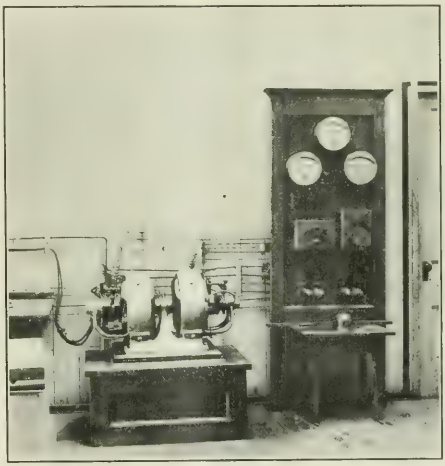


FIG. 7.- MOTOR-GENERATOR AND SWITCHBOARD

ger from fire, but experience has shown that in an experimental room of this sort the entire absence of wood work is desirable.

For conducting high temperature and electrolytic work various new forms of apparatus and methods have been devised, some of which are referred to in the following paragraphs.

In measuring single electrolytic potentials the well-known "calomel" electrode is employed, its e. m. f. being assumed as 0.56 volt, and where convenience and rapidity requires the use of cadmium or other suitable metal, the single values of such are determined in terms of the "calomel" standard.

For measuring small electric potentials with a high degree of accuracy a Leeds potentiometer is available, but for ordinary purposes where a degree of accuracy consistent with unavoidable experimental error is attained, a simpler and much cheaper potentiometer outfit has been designed and constructed in the laboratory which permits an accuracy within one-tenth of one per cent. Two forms of this potentiometer outfit are illustrated in cut, showing apparatus constructed

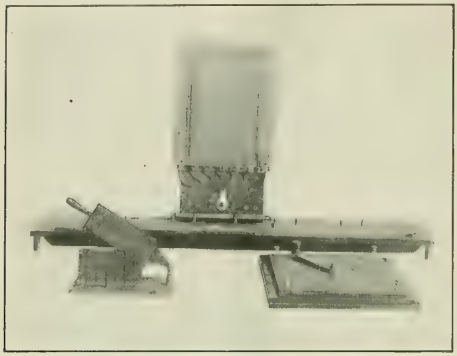


FIG. 8.—SPECIAL CARBON RHEOSTATS.

in the laboratory. It consists of 1000 ohms subdivided into ten 10-ohm coils in series, with nine 100-ohm coils, each of these steps being connected to suitable contact terminals to which radial arms make contact. This is an adaptation of the

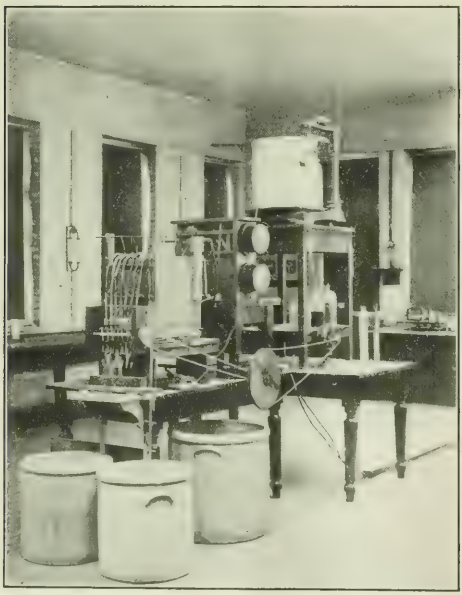


FIG. 9.—EXPERIMENTAL APPARATUS FOR THE PRODUCTION OF CHROME YELLOW.

Ostwald potentiometer, with radial adjustment arms which increase the convenience of working, and in addition there is supplied a 9000-ohm coil, which can be placed in series with the 1000 ohms, increasing the range of measurement ten times. By means of this outfit, potentials varying from less than 0.001 volt to over 100 volts can be measured with an accuracy of one-tenth of one per cent. It is used for the calibration of ampere meters and voltmeters, the measurement of e. m. fs., and resistances by the fall of potential method. It has proved especially suited to the determination

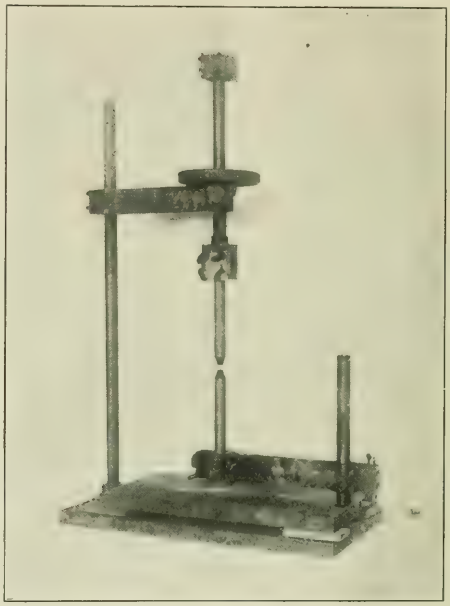


FIG. 10.—VERTICAL ELECTRODE SUPPORTS.

of resistances of very high value, above 100,000 megohms, such as are encountered in the determination of insulation resistances.

The indicating instrument used in connection with this potentiometer is, for ordinary purposes, a horizontal portable galvanometer or millivoltmeter, but where these cannot be used satisfactorily a portable capillary electrometer is employed. The form of electrometer which has been found espe-

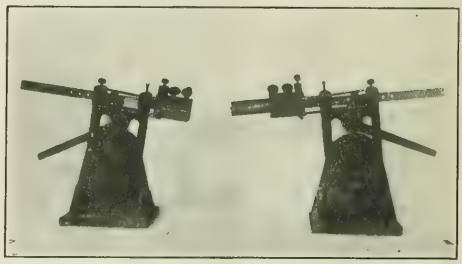


FIG. 11.—HORIZONTAL ELECTRODE SUPPORTS.

cially adaptable is a modification of the well-known Lippmann instrument, and is illustrated in Fig. 16. It is so arranged that there is no possibility of spilling the electrolyte. The position of the meniscus is determined by means of a small microscope fitted with a micrometer eye-piece, and the portability of the instrument and the freedom from vibration influences may be judged from the fact that the meniscus

may be adjusted upon the scale of the eye-piece and after shipment by express may be found ready for immediate use without readjustent. A portable instrument of this sort was constructed with a sensitiveness of 0.00002 volt, and used for several months in a study of the changes of e. m. f. which are set up by iron under various conditions of strain.

FIG. 12.—ELECTROLYTIC WORK TABLES.

For the measurement of electrolyte resistances the well-known methods are employed. A method which has been found of great convenience, overcoming the various sources of error in a degree sufficient to meet commercial requirements is illustrated in Fig. 15, where an ordinary voltmeter is the only indicating instrument employed. The method of operation consists in placing the electrolytic resistance in a rectangular trough of such length as to furnish between the terminal electrodes a resistance having a suitable proportion to the resistance of the voltmeter. The measurement consists in connecting the cell terminals in series with the voltmeter to a 100-volt or other convenient source of pressure. By closing the switch S to (a) the voltmeter gives the total

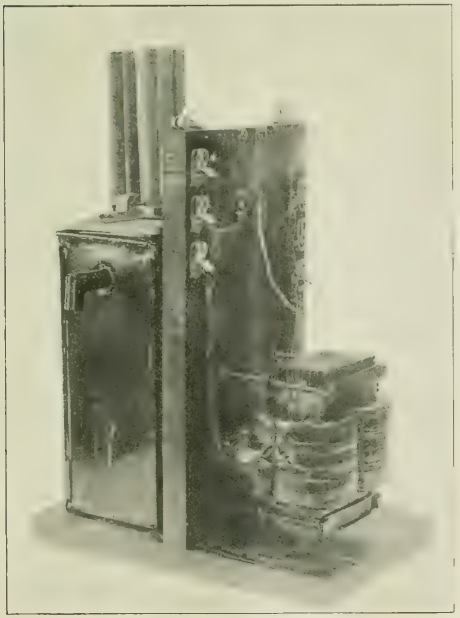


FIG. 13. AQUEOUS RECTIFIER

pressure E, and upon opening the switch the resistance of the electrolyte is thrown in series with the voltmeter, thereby reducing the reading to a value E'. By applying the following formula the resistance of the electrolyte R' is derived, R being the resistance of the voltmeter.

$$R' = R \frac{E-E'}{E'}$$

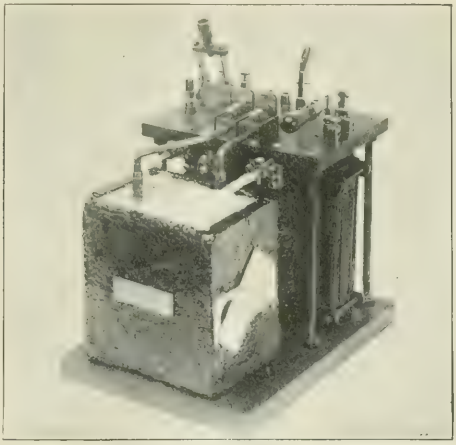


FIG. 11.—RECTIFIER WITH FUSED ELECTROLYTE

This method is especially applicable for the rapid determination of the resistances of the earth, or any high resistance electrolytic conducting material.

Where it becomes desirable to measure the specific resist-

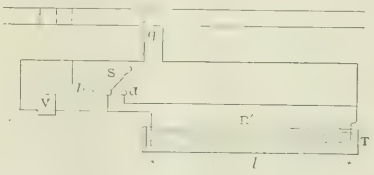


FIG. 15.—MEASURING RESISTANCES.

ance of an electrolyte by simply immersing the measuring apparatus in the solution, as a hydrometer would be used for determining the density, a tube containing the electrodes, as illustrated in Fig. 17, is employed. The measurement can be made by means of a voltmeter, as previously described, or by other suitable means.

An important part of the equipment of an electrochemical laboratory consists in rheostats for adjustment of current values. Some rheostats which have been designed and constructed to meet the special requirements of this laboratory are shown in an accompanying illustration. To obtain a small step-by-step adjustment of current for electrolytic work from a 110-volt source of supply six wall lamp resistance boards are installed. These permit of range of current from 0.1 ampere to 6 amperes in fifty steps, each board being supplied with an ammeter and voltmeter.

Carbon rods mounted on an iron frame and protected by an iron screen constitute a cheap and satisfactory form of rheostat for large volume, low pressure currents. A special form of rheostat for use in the testing of one or two storage cells is also shown. It is a combination of switch

FIG. 16.

and rheostat, the side bearing springs being divided into a number of sections faced with carbon blocks about ¼-inch thick. The blade of the switch consists of a metal frame holding strips of carbon, and the two opposite sides of the switch constitute the terminals of the resistance. The resistance is adjusted by the sliding contact to the exact value desired, this being done by closing the knife of the switch to the desired degree. This form of switch has the advantages of cheapness, gradual adjustment, and large current-carrying capacity.

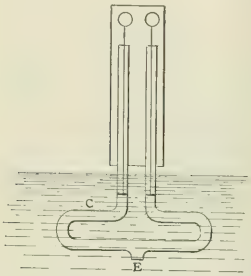


FIG. 17.—MEASURING SPECIFIC RESISTANCE.

In an electroplating room one of the difficulties with rheostats commonly used is the corroding of the contacts which therefore require frequent attention. The wall rheostats illustrated in the photograph from the electrolytic depositing room were designed to overcome this difficulty by enclosing the contact points behind a glass cover. These rheostats have now been in use for five years without giving the least trouble from poor contacts.

A high pressure rheostat of low current carrying capacity, and having a sliding contact adjustment, is made by cutting a circular band in a slate or stone slab and filling this with a mixture of graphite, pumice-stone and a binding material, the relative proportion of the material being determined by the degree of resistance and current carrying capacity required. A considerable number of such rheostats are in use and are found to be durable and cheap, and capable of being heated to about 150° C.

The work of the first semester in the applied electrochemistry laboratory consists in performing such experiments as will give an idea of the various methods of making electrolytic measurements of resistance and potentials, of the oxidation and reduction and other electrolytic effects of the current; experiments illustrating the applicability of Faraday's law to the deposition of metals and production of various chemical reactions. The various details connected with the deposition of nickel, copper and zinc and other metals for plating purposes are studied together with the methods of cleaning and preparing the surfaces both before and after receiving the deposits. The effect of current density, temperature, composition, density and circulation of the electrolyte as regards the influence on the character of the metal deposit are illustrated by a set of experiments. Batteries, both primary and secondary, are subjected to tests of efficiency, resistance, polarization, etc.

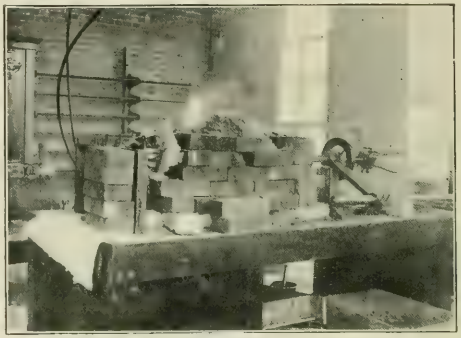


FIG. 18.—EXPERIMENTAL ELECTRIC FURNACE.

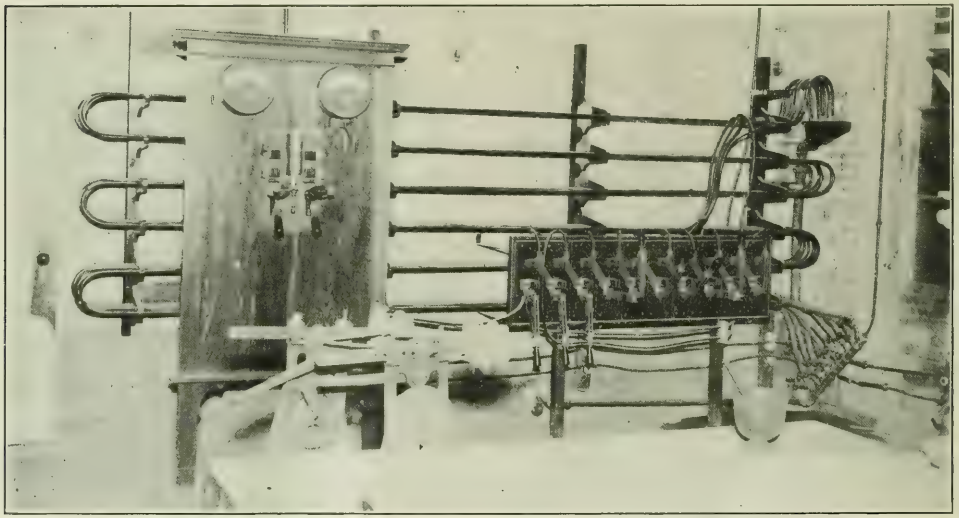


FIG. 19.—RHEOSTAT FOR ELECTRIC FURNACES.

The work during the second semester deals with the operation and study on a miniature scale of various technical applications of electrolysis and high temperature work. This includes the production of hypochlorites, chlorates by the electrolysis of salt solutions; also the production of alkali, chlorine, pigments, metallic sodium, calcium carbide, carborundum, silicon, graphite, aluminium, magnesium, and various other materials of a similar kind.

The thesis work and the graduate study in applied electrochemistry covers largely the study of special problems. While it consists mostly in laboratory investigation it includes also

an examination of the literature bearing on the subject, facilities for which are available in the University and State Historical library, one of the most complete libraries in the country, having complete files of most of the important scientific and engineering publications in English, German and French, together with complete sets of the United States, British and Canadian patents.

Among the investigations which are now under way are the following. A study of the electrolytic refining of iron has been in progress for over two years, and with results which indicate that chemically pure iron can be produced as simply and as cheaply as is the case with copper. About one-half

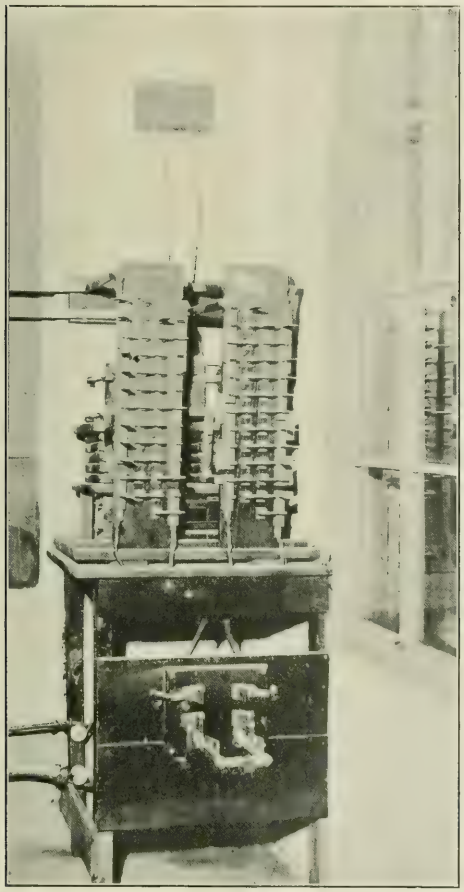


FIG. 20.—20-KW. TRANSFORMER FOR ELECTRIC FURNACES.

ton of this iron has been deposited, chemical analyses of which show no trace of carbon, manganese, silicon and other impurities commonly found in iron. An accompanying illustration shows about 200 pounds of iron in the form of cathodes, test specimens, etc.

A study of the electrolytic rectification of the alternating current, utilizing the well-known property of aluminium and other metals for this purpose, has resulted in the development of several types of electrolytic rectifiers to fulfill commercial requirements. Two types, utilizing the fused electrolyte and aqueous solutions, are shown in the illustrations.

A study of the distillation and recovery of zinc direct from its sulphide ores has yielded results of value, and the extraction of molybdenum directly from its sulphide without the usual preliminary roasting has been satisfactorily accomplished. The separtion and recovery of several of the rare elements from their ores is being studied by electrolytic and electrothermal methods.

Investigation of the conductivity of various fused materials is being made for the purpose of determining a suitable ma-

FIG. 21.—NEW CHEMICAL BUILDING.

terial for an electrically heated fused bath for tempering high-speed tool steel, the requirements of which are non-corrosive action on the steel, and electrodes, and maintenance of the electrolyte without decomposition or appreciable volatilization at about 1400° to 1500° C.

Other investigations deal with the fusion of quartz, reduction of tungsten, commercial tests of the Edison storage cell, resistance and counter electromotive force of copper refining tanks, and the determination of such physical properties of carbon and graphite as relate to the use of these materials for electrode purposes and the construction of electric furnaces.

Among experimental work which has been done within the past few years may be noted the determination of efficiency, cost and commercial considerations relative to the production of hypochlorites, tests on storage batteries of different makes, and upon storage battery plants, and a comparison of most of the dry cells on the market to determine their life, capacity, resistance, and other properties. An extended investigation upon the corrosion of iron showed, among other interesting facts, that iron under strain causes a change in the contact potential of the metal toward an electrolyte, so that a curve showing such changes is similar to the curve of the stress-strain diagram.

An electrolytic stripping process was developed for the removal of copper, brass and silver from iron. It has found extensive application in the bicycle factories of the country as an adjunct to the brazing process.

Zinc plating has been the subject of a large amount of work, and in addition to determining the conditions for the production of the best deposits, a comparison has been made of the protective properties of zinc applied by the electrolytic and by other methods.

A process has also been worked out for the deposition of durable, adherent deposits upon aluminium, as described in the Electrochemical Industry, March, 1904. Another line of work to which considerable attention has been given is the production of chrome yellow and other pigments.

Various other researches which have produced interesting and valuable results might be noted, but the ones mentioned serve to indicate in general the nature of the work undertaken.

Current Notes.

Electric Furnace Processes in the Iron and Steel Industries.—The possibly great importance of industrial developments in this line is indicated by the interest with which our series of articles on various processes in this field has been received. Mr. P. McN. Bennie's article in our January issue, which is a condensed translation of Mr. G. Gin's description of his latest process, with some additional critical notes, has been reprinted literally (with the addition of a cost sheet at

the end, while we gave only a summary of the same) in the organ of the Faraday Society, the *Electrochemist and Metallurgist*, of March, and in the issues of April 23d and 30th of a New York electrical journal. While both journals do not give credit to us in their reprints, we are glad to see that Mr. Bennie's translation and annotation, as specially prepared for our columns, has found the approval of our esteemed contemporaries.—The committee appointed by the Canadian Government for the purpose of investigating the different electric furnace methods in use in various plants in Europe, has just returned, and will submit its report early in next month. While no details are given out at present, it is stated that the trip of the commission has been entirely successful, and the committee is convinced that by one of the processes which it has examined, the production of steel from ores with utilization of Canadian water powers will be a commercial success. The commission consisted of Dr. Haanel, chairman; Professor F. W. Harbord, of Copper Hill, Surrey, England, metallurgist to the Indian Government; Mr. C. E. Brown, formerly of the General Electric Company, Peterboro; Mr. Eric Nystron, mining engineer, connected with the Civil Service in Ottawa, and Mr. Thomas Cote, secretary.—The Keller furnace, described in our issue of January, 1903, and August, 1903, is stated to be applied at present on a large scale at Livet, France. They have about 4,000 hp. in operation there, making ferro-alloys, special steels, etc.

American Electrochemical Society. The following gentlemen were elected members of the American Electrochemical Society on March 4: Earl T. Ragan, Des Moines, Ia.; Margaret A. Gleaves, New York; Sarat C. Rudra, New York; Oliver P. Watts, Madison, Wis.; Edwin A. Zeller, Jr., Philadelphia; C. M. Kline, Philadelphia; Lucien Ira Blake, Lawrence, Kan.; George McQuilkin, Jr., Quincy, Mass.; Gideon Boericke, Philadelphia. The following gentlemen were elected on April 2: J. M. Barrett, Pittsburgh, Pa.; J. T. Willams, Stamford, Conn.; Franz Salzer, Philadelphia; Adelbert H. Richards, Colorado Springs, Col.; J. D. Pennock, Syracuse, N. Y.; A. J. Ewing, Minas Geraes, Brazil; F. A. Holton, Washington, D. C.; Henry Gall, Versailles, France; T. B. Stevens, Colorado Springs, Col.; George A. Hulet, Ann Arbor, Mich.; S. Sakai, Kokura, Buzen, Japan; Paterno, Rome, Italy; G. B. Chorpening, Clarksburg, W. Va.; F. P. Dewey, Washington, D. C.; A. E. Bonna, Rome, Italy. The following were elected on April 7: Robert King, Toronto, Ont., Canada; Addis Bliss Albro, New York; Ernest Stütz, New York. The names of the following gentlemen will come up for election at the May meeting of the board of directors: Herbert Haas, Redding, Shasta county, Cal.; Clarence I. B. Henning, Santa Cruz, Cal.; Franz von Kuegelgen, Holcombe Rock, Va.; F. H. Chapin, Minneapolis, Minn.; H. W. Buck, Niagara Falls, N. Y.; Henry N. Stokes, Washington, D. C.; F. A. Wolff, Jr., Washington, D. C.; Henry Walter Sykes, Syracuse, N. Y.; Charles Brandeis, Montreal, Canada; Charles H. Clarke, Berlin, N. J.; Horace H. Emrich, Perth Amboy, N. J.

Lehigh University. Among the subjects of thesis to be presented by candidates for degrees, Lehigh University, South Bethlehem, Pa., June, 1904, are the following: S. Le Roy Carron, "Plans and estimates for ozonizing plant for the sterilization of the water supply of Bethlehem, Pa.;" C. R. Peebles, "Manufacture of steel in the electric furnace;" R. L. Herrick, "Tests on the applicability of the electro-cyanide process to a Brazilian gold ore;" H. P. Barnards, "Manufacture of potassium chlorate by the electrical process.

Experiments with Radium.—A report from Vienna states that at the request of the Academy of Science, the Austrian Minister of Agriculture, "in order to facilitate the solution of certain important questions relating to the nature of radium," has ordered that from January 1 until further notice no trading should be permitted in the residues from the manufacture of uranium colors at Joachimsthal, and that 10,000 kilogrammes of those residues should be reserved for purchase by the Academy, and another 10,000 kilogrammes for M. Curie, the discoverer of radium, in Paris. These consignments are to be devoted entirely to the purpose of scientific experiment.

SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.

Industrial Electrochemistry.

Applications of Electricity to Metallurgy.—The March issue of the *Technology Quarterly* contains a lecture by J. W. Richards on the applications of electricity to metallurgy. After an introduction on the metallurgical methods of treating ores, the author remarks that electricity is used to assist the metallurgist in three fundamentally different ways, viz., mechanical, thermal, electrolytic. The mechanical applications of electricity comprise the electromagnetic and electrostatic processes of dressing and concentrating ores. The thermal methods use the electric furnace which is either an arc or a resistance furnace. The author gives a review of the chief features of both types, and sums up the particular advantages of electric furnace heat as follows: First, heat can be generated up to 350° C., which is at least 1500° higher than can be obtained in fuel-fed furnaces. Secondly, it is applied internally, or in such close contact with the material to be heated that it is greatly more efficiently applied than the ordinary forms of heating. One horse-power-year cost from $10 to $25 at established water-power installations, and its heat-producing power is 15,000 calories per day, or the equivalent of the full calorific power of 2 kg. of good coal. This gives the heating power of a horse-power-year as that of 730 kg., or ¾ of a ton of coal. But for a given heating effect the electric heat can be applied (for instance, for melting steel) at an efficiency of 75 per cent, whereas the heat of combustion of coal is at most applied at an efficiency of 25 per cent. In general, therefore, electric heating will cost less where coal costs per ton over one-half of the price paid per electric horse-power-year. This is on the assumption that coal can be so used as to produce the effect desired, and ignoring many other advantages which electrical heating possesses, and which in many cases make its use preferable even at several times the cost of a ton of fuel per horse-power-year. Electrolytic methods, as applied to metallurgical purposes, are classed under three heads. First, the material being treated is the electrolyte or part of the electrolyte; second, the material is the anode or placed in contact with the anode; third, the material is the cathode or placed in contact with the cathode. The author discusses the phenomena of electrolysis and its attendant chemical phenomena, the reducing action at the cathode and the perducing (oxidizing) action on the anode. In electrolyzing a fused metallic salt, it is almost an invariable rule that the output of metal will represent more nearly 100 per cent ampere-hour efficiency the nearer to its melting point the salt is when electrolyzed. If a fusible compound of the metal desired is not readily obtainable or a suitable one not to be found, the problem may be solved by the method of dissolving it in a solvent, as Hall does in his aluminium process. Hall sought for a fusible salt which would dissolve alumina, and be electrically more stable than alu-

mina. He found the solvent in a mixture of fused sodium fluoride and aluminium. The author expresses his surprise that the same priciple has not been applied to the reduction of other metallic oxides. Easily fusible silicates of manganese and calcium, for instance, would dissolve manganese oxide to a considerable extent which would be decomposed by the passage of the current. He considers this principle one of the most promising fields for experiment in the whole realm of electrometallurgy. Salom's principle of reducing lead from galena by cathodic reduction seems also to have a wide range of application.

Manufacture of Iron and Steel in the Electric Furnace.—In *Dingler's Polytechn. Jour.*, April 2 and 9, A. NEUBURGER gives a review of the processes of Stassano, Heroult and Keller for producing iron and steel from ores in the electric furnace. His account of these processes does not seem to contain any new details. The author arrives at the following conclusion. He refers to the opinion of Goldschmidt that the electric manufacture of special steels is capable of competing with crucible steels in Germany. Gin is of the same opinion. He thinks that the electrometallurgical treatment of iron ores is impracticable in countries with cheap coal and cheap freight rates, but that the prospects are very favorable for the electric manufacture of the better grades of steel from cast-iron, made in the blast furnace. Both Gin and Goldschmidt think that the Martin furnace may be advantageously replaced by apparatus in which electrical energy is used. The best results will be obtained—even in districts where coal is plentiful—if the waste gases of the blast furnace are utilized for producing the electrical energy; electric power will then be so cheap as to be able to compete with water power, and Gin considers such a plant as of ideal technical perfection. It would represent a combination of an ordinary blast furnace, a Bessemer converter for making the cheaper grades of steel, and an electric furnace for making the fine steels. The author finally remarks that in Germany the electric manufacture of tool steels has recently been undertaken on a commercial scale.

Ferro Silicon.—While in the commercial manufacture of ferro-silicon, carbon is always used as a reducing agent, an important advantage would be obtained if it was possible to bring about a reaction between sulphide ores and quartz as to yield ferro-silicon and sulphur dioxide according to the equation $FeS + SiO_2 = FeSi + SO_2$. From a patent, taken out by Aschermann, it would appear that such a reaction can be produced. In a paper published in *Metallurgie*, April 8, and *Stahl und Eisen*, April 1, AMBERG gives, however, an account of a series of laboratory experiments in which he tested the above reaction. He used iron sulphide and silicon dioxide in various greatly varying proportions, and also used an addition of lime, without obtaining satisfactory results, the reaction being very slow and the yield of ferro-silicon small, so that he does not think that the reaction which really takes place is represented by the above equation. He has little hope for a commercial success in this direction.

Calcium Carbide.—Calcium oxide is reduced by carbon only at a temperature at which the former becomes liquid. The manufacture of calcium carbide, therefore, requires an enormously high temperature, and an electric furnace to produce it. H. MOISSAN points out, however, the possibility, although not practicability, of another method, in a paper published in *Comptes Rendus*, March 14, and abstracted in the London *Electrician*, April 8. It is based on the fact that metallic calcium combines with lamp black to produce calcium carbide at any temperature above red heat. In any electrolytic process, therefore, where calcium is produced in contact with carbon at a red heat, calcium carbide is formed. His new carbide process is based on these considerations, but it apparently has no commercial value, since the carbide obtained is firmly embedded in a fused mass of calcium chloride and fluoride. A graphite crucible, which serves as the positive pole, is filled with calcium chloride fused by means of a small electric arc. A vertical rod of graphite serves as a negative electrode. The chloride is put in gradually, and after the first fusion electrolysis is carried out by means of a current of 10 to 15 amperes at 120 volts. Chlorine is given off freely, and after an hour the process is stopped and the crucible broken. Under the crust is found a mass with a crystalline fracture. The central portion dissolves in water, and evolves a mixture of gases containing some 14 per cent of acetylene, the rest being hydrogen. The process is greatly improved by mixing the chloride with a quarter of its weight of fluoride, which makes the fused mass more fluid and the conduction of the current more regular. The amount of carbide obtained is small, but it may be increased by adding to the liquid a coarsely-powdered mass of petroleum coke.

Ozonizer.—The Elworthy ozonizer is described in the April number of *Elektrochem. Zeit.* by the inventor. From the apparatus of Siemens & Halske it is distinguished by the feature that the low temperature which is required for getting a sufficient yield of ozone is not produced by water cooling, but by using a high-speed for the passage of the air through the ozonizer, and by passing the air twice through a field of silent discharges. Metal solenoids, which form the poles of the silent discharges, are placed in a small glass tube, and in a large glass tube, which surrounds the former. The air passes first through one tube, and then through the other. Ten of such tubes are combined in one apparatus, which is operated by an alternator giving three to four amperes and 125 to 135 volts, the tension being raised in a special transformer to 11,000 to 12,000 volts. The air is passed through the tubes by means of an air pump. The yield of ozone is 60 to 70 grams per kilowatt-hour, the concentration of ozone in the mixture of air and ozone 0.4 to 0.5 gram of ozone per cubic meter. The ozonized air leaving the apparatus has a temperature of 20° higher than the surrounding atmosphere. To obtain a higher concentration of ozone, the air is passed through several apparatus in series, cooling devices being inserted between each two apparatus. While ozone has found practical application so far mainly for the sterilization of water, it is stated that it may be used also in bleaching, for ageing wine, in the manufacture of soap, perfumes, etc., and especially in the petroleum industry, since it is claimed that all kinds of petroleum when treated with ozone for two to ten hours, lose the strong petroleum odor and give a clear, quiet white light like incandescent lamps. Ozone may also be used as an oxidizing agent in special cases of chemical industries.

Fixation of Nitrogen from Air.—An experimental study of the yield of nitrogen oxides from air by the flame discharge, and on the influence of the length of flame and of the temperature was made by F. VON LEPEL, an account being given in *Berichte*, 1904, vol. 37, page 712, and abstracted in the *Jour. Soc. Chem. Ind.*, April 15. When the discharge occurs between a copper wire anode and a carbon cathode, the poles are clearly differentiated, both by the naked eye and by the spectroscopic appearance of the flames; and this difference is also shown in the chemical effects of the discharge, for the gases drawn from the immediate vicinity of the cathode contain a much larger proportion of nitric oxide than those taken close to the anode. Receding from anode and cathode, however, the proportions respectively increase and decrease, so that at 5 mm. from the anode, the air surrounding the flame is richer in nitric oxide than at 20 mm. from the cathode. Naturally the highest total yield of nitrogen oxide is got by taking the air surrounding the flame along its whole length. The author considers that the formation of nitrogen oxides is due to direct electrical action, and is not solely thermal, as Muthmann and Hofer suppose. In experiments in which the voltage and current in the primary were kept constant, the temperature of the air at a certain distance from the flame (and hence, presumably that in the flame itself) rose as the speed of rotation of the anode was increased from zero, and also

as the length of the flame was increasd. The yield increased with the temperature (to a quickly reached maximum) only when the anode was fixed. The best yield was always obtained with a medium temperature. The frequency of the interrupter was also varied, but moderate frequency was found to give the best results; a Wehnelt interrupter is not suitable. The yield is increased by soaking the cathode in various salt solutions, such as potassium hydroxide, copper sulphate, or titanium chloride. The solution of nitrate and nitrite obtained by neutralizing with sodium carbonate the aqueous solution of the nitrous gases produced by the process can be used as manure, and is apparently as efficient as Chili saltpetre, so that for this purpose the conversion of the nitrite into nitrate is not necessary.

Electrolytic Preparation of Iodoform from Acetone.—J. E. Teeple publishes an interesting paper on this subject in the February issue of the *Journal of the American Chemical Society.* He refers to Schering's electrolytic method of preparation of iodoform from alcohol and shows that the preparation from acetone would have certain advantages. In his method the electrolyzing cell was a rather deep crystallizing dish; the anode, a piece of platinum foil of 0.4 sq. dm. surface lying on the bottom of the dish; the cathode, a piece of platinum wire just dipping beneath the surface of the liquid. A stirrer driven by a small motor kept the solution in active motion. The cell stood in a bath and the temperature was usually kept at about 25° C. or lower. The solution consists of 25 or 30 grams of potassium iodide, 200 to 250 cc. of water, and 2 cc. acetone. He used an anode current density of one to six ampere per sq. dm., and an e. m. f. of 3 to 12 volts, according to the concentration, the temperature, the current density and the distance between the electrodes. When the perfectly neutral solution of potassium iodide was then electrolyzed in the presence of acetone without a diaphragm, the current yield was only about 50 per cent, but it may be made almost theoretical if the excess of alkali is neutralized as soon as it is formed. As reagents for neutralizing he used successfully carbon dioxide or hydrochloric acid or hydriodic acid or iodine; the last seems to be the most practical one.

Silver Plating.—A note in *Metal Industry,* April, deals with cyanide versus chloride in the silver bath, the bath consisting of a solution of either the cyanide or chloride of silver in cyanide of potash. Chloride is sometimes preferred because it is much more rapidly made than the silver cyanide. On the other hand, platers who produce the highest grade of work, and that which wears the best, invariably use the cyanide of silver. It is said that work plated in a chloride bath does not stand the burnishing nearly as well as that produced in the cyanide bath, but is much more apt to strip under the tool. The solvent action of the anode is also much less, and it is much more difficult to keep the bath in a uniform working condition.

Brass Plating.—The April issue of *Metal Industry* contains an article by F. P. Davis on brass plating solutions, their use and abuse. He classifies brass solutions into those suitable for heavy deposits and those for light, bright deposits, to be lacquered with no further finish. Both baths are made from freshly prepared carbonates of copper and zinc; two parts of weight of the former and one part of the latter. The cell is first half filled with pure water with some pure cyanide of potash, then the copper carbonate is added and afterwards the carbonate of zinc, dissolved in cyanide, is added. The bath is used at a temperature from 100 to 110° F. and the solution should stand at 5 to 5½ Beaume. The anode is made of first quality clean yellow brass, and its surface should be equal or in excess of that of the cathode. The rules for preparing the solution, with the precautions to be taken, are given at some length.

Cadmium.—In the March issue of the *Electrochemist and Metallurgist,* S. Cowper-Coles gives a review of what has been done in the electrodeposition of cadmium and its alloys.

Theoretical and Experimental.

Determination of Latent Heat of Fusion and of Specific Heat of Metals at High Temperature.—While this is a matter of considerable importance for applying the methods of thermochemistry to electric furnace reactions only few data are so far available. In *Metallurgie,* March 22 and April 8, F. Glaser describes a method which he has found useful for determining the specific heats of solid and fluid substances at temperatures up to 1100° C., having applied it to measure the specific heat of lead, zinc, aluminium, copper and tin, and to calculate the latent heat of fusion. The principle of the method is well known, the substance to be investigated being heated to a certain temperature, then quickly brought into water and the temperature increase of the latter being measured. His apparatus is shown in Fig. 1. The calorimeter is a sheet-iron box, 350 by 350 by 400 mm., placed in a wooden box upon pieces of rubber, the space between the iron box and the wooden box being filled with wood, and two stirrers are placed in opposite corners. The total quantity of water was determined before each experiment as follows: The calorimeter was filled partly with water, the stirrers were started and the course of temperature was taken; simultaneously another quantity of water was brought to a higher temperature, the course of its temperature was measured, and shortly before pouring it into the calorimeter the weight was determined. The increasing temperature in the calorimeter was then measured. Above the calorimeter, the electric furnace is placed. Upon a firebrick ring of 65 to 70 mm. internal diameter is placed a carbon ring which serves as one pole for the current and surrounds the lower end of a tube of refractory material. Upon the carbon ring an external cylinder of firebrick is placed so that there is a space left between it and the internal refractory tube. This space is filled with small pieces of retort carbon. The upper end of the apparatus is closed by two carbon blocks, through which the thermo-element is introduced. The metal to be tested is placed in the inner tube, and the method by which it is dropped into the calorimeter is clearly shown in the figure. The author gives the results of his measurements, the specific heats being determined first for ordinary commercial metal, and then for chemically pure metals. The specific heats of the pure metails are generally somewhat smaller. The latent heat of fusion for one gram was found as follows: Lead 4.78 calories, zinc 29.86 calories, aluminium 76.8 calories, copper 41.63 calories, tin 13.62 calories. The only difficulty at high temperatures was experienced with molten copper at 1190° C. When a quantity of 3 to 4 kg. was dropped into the water there was something like an explosion. By applying a larger water calorimeter and more energetic stirring the author hopes to be able to extend the higher limit of temperature further upwards. For the latent heat of fusion of metals, J. W. Richards (*Chem. News,* vol. 75, page 278) has developed an empirical rule according to which one-third of the total heat absorbed by the substance from the absolute zero point of temperature to the point of fusion, equals the latent heat of fusion. He found that in general the calculated and measured values agree together, with the exception of aluminium, for

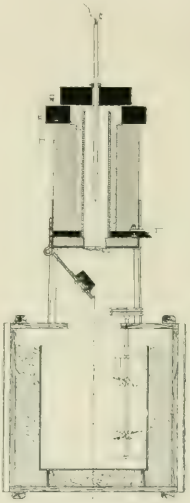


FIG. 1. APPARATUS FOR DETERMINING SPECIFIC HEATS.

which 70.4 was calculated and 100 was measured. The value found by the present author—76.8—agrees better with the calculated value, while in the case of zinc the difference between the calculated and measured values becomes somewhat greater.

Electrical Conductivity of Aqueous Solutions at High Temperatures.—The February issue of the *Journal of the American Chemical Society* contains a lengthy and important paper by A. A. NOYES and W. D. COOLIDGE. After working three years, they succeeded in constructing a platinum line bomb with electrodes insulated by means of quartz crystal cylinders. The bomb remains perfectly tight at any rate up to 306°, and occasions only an unimportant contamination even in salt solutions as dilute as 1-2000 molar. It yields conductivity measurements accurate to 0.25 per cent or less, and at the same time makes possible specific volume determinations which are essential to the interpretation of the results. The authors have thus far been able to investigate only two dissolved substances—potassium and sodium chloride—but have made conductivity and specific volume measurements with these solutions at various temperatures ranging from 26° to 306° C., and at various concentrations between 0.1 and 0.0005 molar. Even at the highest temperature the dissociation calculated from the molecular conductivity ratio does not change with the concentration in much closer accord with the requirements of the mass-action law than at the ordinary temperature. The empirical formula of Kohlrausch $\Lambda_0 - \Lambda = KC^{\frac{1}{3}}$ was found to represent the results most satisfactorily. The conductivity values extrapolated for infinite dilution, and therefore the migration velocities of the ions, were found to be an approximately linear function of the temperature throughout the whole range of temperatures in the case of sodium chloride, and up to 218° C. in the case of potassium chloride, the deviations being moreover not very large (3.5 per cent) even at the highest temperatures with the latter salt. The ratio of the conductivity of KCl and NaCl at infinite dilution decreases from 1.19 at 18° to 1.04 at 306°, showing that the migration velocities of the sodium and potassium ions are slowly approaching equality. The degrees of the dissociation of the two salts are nearly identical at all temperatures and concentrations. The dissociation in a 0.1 normal solution has approximately the following values, 84 per cent at 18°, 79 per cent at 140°, 74 per cent at 218°, 67 per cent at 281° and 60 per cent at 306°.

Electric Conductivity in the Neighborhood of the Critical Point.—The electrical conductivity of solutions has recently been applied to the study of the critical phenomenon. It has been shown, not only that solutions conduct beyond the critical point, but that the vapors of these solutions become conducting before the critical point is reached. In a paper published in the January and February issues of *Physical Review*, C. A. KRAUS gives an account of measurements of the change of the electric conductivity of solutions in methyl alcohol in the immediate neighborhood of the critical point. Solutions in methyl and ethyl alcohol possess maxima of conductivity, the former in the neighborhood of 150°, the latter in the neighborhood of 100°. Such solutions conduct beyond the critical point, those in methyl alcohol conducting much the better. The temperature coefficint of solution in methyl alcohol undergoes a certain change at the critical point. An unsaturated vapor solution exhibits no discontinuity at the critical point of the solvent. Solutions which consist of mixtures of gasogenous and liquidogenous molecules exhibit a great change of the conductivity immediately beyond the critical point, but a discontinuity of the tangent cannot be established. Methyl alcohol presents the same phenomena of non-homogeneity beyond the critical point as do other liquids studied in this connection. The author also studied the conductivity of solutions possessing the same concentration of solute and different densities of solvent For large quantities of solvent present, the conductivity is nearly proportional to the quantity of solvent. For smaller quantities of solvent present the ratio of increase of conductivity is much smaller. As the critical point is approached, the ratio of increase of conductivity with increase of solvent is increased. The vapor of a solvent may become a very good conductor in the neighborhood of the critical point. The conductivity increases very largely for a saturated vapor as the critical point is approached, owing to increasing density of both solvent and solute.

Action of Salts upon Amalgams.—In our February issue, page 67, we gave an abstract of an article by Fernekes on the action of sodium and potassium amalgams on various aqueous solutions. The author concluded that his observations could not be explained by the electrolytic dissociation theory, and that they were readily explained by a theory of Kahlenberg. The March number of the *Journal of Physical Chemistry* contains a paper by G. MCP. SMITH, who thinks that the action referred to in the former paper "could be much more plausibly explained by the ionic theory of Arrhenius than by the hypothesis of Kahlenberg, as follows." A solution of potassium chloride, containing positively charged potassium ions, in contact with sodium amalgam brings about the replacement of the sodium in the amalgam by potassium in the following manner. The positive electron of the potassium ion is neutralized by the negative electron of a neutral sodium atom (containing both a positive and a negative electron) upon coming in contact with the latter and thus leaves the sodium atom positively charged, *i. e.*, an ion; the potassium atom entering into the amalgam and the sodium ion into the solution. How much sodium is thus replaced depends upon the condition under which the experiment is carried out. If a relatively large number of potassium ions are in the solution, as compared with the number of sodium atoms in the amalgam, the sodium of the amalgam is according to the law of mass action almost entirely replaced by potassium, and after this has happened, the potassium (and the remainder of the sodium) in the amalgam is free to act on the solution, which now contains both potassium and sodium ions. This accounts in a very satisfactory manner, for example, for the slow action of sodium amalgam on a solution of potassium chloride. At the beginning, the main process consists in the replacement of sodium by potassium, and, as soon as an equilibrium has been approached in this direction, the resulting amalgam is free to act on the water of the solution with the evolution of hydrogen, and the formation of potassium (and sodium) hydroxide. It is now easy to see why this action is retarded. The sodium and potassium ions of the solution tend to prevent the entrance of more sodium and potassium in the ionic state. He gives rules for the preparation of the amalgam containing sodium from potassium amalgam.

Decomposition Curves of Lithium Chloride in Alcohols and the Electrodeposition of Lithium.—The March issue of the *Journal of Physical Chemistry* contains the complete paper by H. E. PATTON and W. R. MOTT on this subject, an abstract of which was published in ELECTROCHEMICAL INDUSTRY, August, 1903. The authors remark that they reserve all patent rights and state their claims broadly as follows: They have discovered and used new classes of solvents for the electrolytic separation of alkali metals (such as lithium, sodium, etc.) and alkaline earth metals (such as magnesium, calcium, strontium, etc), and other metals not easily obtained from aqueous solutions. They define and claim as their invention, the use of organic solvents fulfilling the two conditions: First, there should be present in the solvent not less than three carbon atoms. Second, one or more of these carbon atoms should (*a*) be the center of a carbonyl group (which includes aldehydes and ketones, such as acetone, etc.) or (*b*) have bound to it an hydroxyl group (this includes propyl alcohol, butyl alcohol, amyl alcohol, phenol, etc.).

Non-Aqueous Solutions.—The February issue of the *Journal de Chimie Physique* contains a very useful summary by P. DUTOIT on the numerous researches on conductivity, dissociation and properties of electrolytes in solvents other than

water. The subject is discussed under the following headings: Ionizing power, electric conductivities, transport numbers, molecular weights, differences of potential and electrolysis, properties of dilute solutions, chemical reactions. Since the paper itself is a concise statement of our present knowledge of the subject it cannot be briefly extracted. As an appendix a long list of papers on the subject is given.

Dielectric Capacity of Atoms.—The electron theory imparts more interest than ever to the investigation of the properties of atoms. At the present stage of this theory the electrical properties of atoms demand investigation from every possible point of attack. In a paper published in the April issue of the *Philosophical Magazine*, W. Sutherland discusses the dielectric capacity of the atom. He had formerly developed a theory which enabled him to calculate the ionic mobility from certain constants, among which was the dielectric capacity of the stuff of the atom. If the latter would be calculated from the refractive index according to Maxwell's well-known formula, his formula for ionic mobility would lead to approximately correct results in some cases, but to absolutely wrong results in others. He concludes that if the ions, besides their free charges contain neutral electric doublets (for instance a monovalent chlorine ion being assumed to have combined with it one negative electron and three doublets, each doublet consisting of a positive and a negative electron) then the presence of these doublets may produce an abnormal effect on the propagation of light, and we shall not be justified in using Maxwell's relation for finding the dielectric capacity from the refractive index. The author now proceeds in the reverse way. He bases his calculations on his formula for the ionic mobility and calculates from Kohlrausch's mobilities the dielectric capacity of the ion. The results are given in a table which shows that on this basis the dielectric capacity of an atom becomes directly proportional to the valency and inversely proportional to the square root of the volume of the atom. It is interesting to find that valency which Faraday proved to be of fundamental importance in his electrolytic law, is of similar importance in connection with dielectric capacity. As to the physical significance of the above law, he gives the following train of speculation. As he has formerly shown, cohesion can be traced to the mutual attractions of the electric doublets in molecules, acting like minute magnets; thus cohesion is an electrical phenomenon. By following a similar train of reasoning, it can be shown that rigidity in solids is a mechanical result of the electric doublets in the molecules. At absolute zero the rigidity is equal to the electric energy of these doublets per unit volume. But to express this electric energy we must regard it as proportional to the square of an electric quantity associated with a molecule. Thus, rigidity is proportional to the square of an electric quantity. Now the above law for the dielectric capacity of the atom means that the square of dielectric capacity divided by valency for an atom when multiplied by the volume of the atom is the same for all. It seems, then, as though a certain stock of electric energy associated with the electrons in an atom were the same for all atoms. The above law seems to be of a similar nature to that of Dulong and Petit, and of the fundamental law of molecular physics which makes the kinetic energy of translation of all molecules at a given temperature the same. A conclusion to be drawn directly from the law is that the ionic velocity is directly proportional to the square root of the radius. This brings out neatly the old paradox about ionic velocities. Hitherto it has been assumed that the ionic velocities have been measured with the same driving force for all ions. The result that a large ion like that of K travels faster than a small one, like that of Li under the same driving force in a resisting medium is, indeed, puzzling until, in taking account of the dielectric capacity of the atom, we see that the driving forces assumed equal, are in reality not so at all.

Indicators.—An account of two investigations on the sensitiveness of indicators, by W. Salessky and B. Fels is given in the *Zeit f. Elektrochemie*, March 25. For investigating the sensitiveness of indicators Nernst has proposed to determine the potential difference of a hydrogen electrode against a solution provided with the indicator to be tested, while it is about to change color. Salessky shows that it is possible to determine the concentration of the H ions at the moment when the color changes, by making use of concentration cells. Fels has determined the concentration of the H ions by another method and found that both methods give approximately the same results.

Laboratory.—A description with drawings of the new laboratory for physical chemistry and electrochemistry at the Institute of Technology of Karlsruhe, is given by Le Blanc in *Zeit. f. Elektrochemie*, April 8.

Electrolysis of Water.—A simple and inexpensive apparatus for the electrolysis of water for lecture experiments in small colleges is described by J. L. Beeson in the March issue of the *Journal of the American Chemical Society*. It is essentially a glass tube exactly of the general form of a tuning fork with graduated arms and platinum wires fused in each arm.

Batteries.

Theoretical Capacity of Lead Accumulators.—In *L'Industrie Electrique*, March 25, Loppe publishes a theoretical article in which he calculates the very highest ampere-hour and watt-hour capacities which a lead accumulator can have per kilogram of total weight, if of the highest perfection, which can be obtained in practice. The calculations are based upon the amounts of material required for the chemical action according to Faraday's law, the reaction being assumed to be that required by the double sulphate theory, and the following assumptions are further made: The "practical capacity" of an accumulator is two-thirds of the "total capacity" (the latter being the capacity, if the discharge is driven down until the e. m. f. becomes zero). For the ratio of the weight of active material to the total weight of the plates the high value 0.8 is assumed. For the calculation of the weight of the electrolyte he assumes that at the end of the charge the elctrolyte has a density of 1.285, and at the end of a discharge 1.125. For the ratio of the weight of the total cell to the weight of plates and electrolyte together the low value of 1.15 is assumed. All these assumptions represent conditions under which the utilization of the active materials in the accumulator would be extremely high, so that the results at which he arrives represent maximum figures which one has to strive at in practice rather without hoping to attain them. He finds that under these conditions a total weight of 35.57 grams per ampere-hour capacity is required. This weight is the sum of that of the electrodes, 15.38 grams; electrolyte, 15.55 grams, accessories, 4.64 grams. For the maximum capacity per unit mass of a lead accumulator he, therefore, finds 28.1 ampere-hours per kg. and 53.39 watt-hours per kg.

Weston Cell.—Considerable work has recently been done on the Weston Cell. Two papers by Carhart and Hulett and Wolff on this subject are extracted in the report of the Electrochemical Society Meeting on another page of this issue. The March issue of the *Journal of Physical Chemistry* contains a paper by H. T. Barnes and S. P. Lucas, who think that it is a matter of small moment which cell, the Clark or the Weston, is adopted as an official standard, since the ratio of the one to the other is known so closely. Both cells have points to recommend them for different types of work, but it is evident that the Clark cell, with its high-temperature coefficient, will retire more completely into the laboratory as time goes on, leaving to the Weston cell the more active part as a general working standard. All forms of the Clark cell, containing a saturated solution, have the same temperature coefficient, the only type possessing a different one being the Carhart-Clark with dilute solution. In the case of the Weston cell it seems from the investigations of the authors that four

coefficients are possible, depending on the state of the cadmium sulphate solution. Cells with solution saturated at 0° C., have practically no temperature coefficient. Cells with a saturated solution of constant strength have a temperature change of 0.0038 per cent per degree. Cells with moist crystals and a 13 per cent amalgam have a temperature change of 0.0055 per cent and cells with moist crystals with a 14.7 per cent amalgam have a temperature change of 0.008 per cent per degree. The authors confirmed the mean value obtained at the Reichsanstalt for the ratio of the Clark at 15° to the Weston at 20°, which is 1.40665. In the February issue of the *Physical Review*, S. J. BARNETT gives in form of curves the results of a series of experiments on the polarization and recovery of cadmium cells.

Primary Cell.—A Faraday Society paper by E. G. P. BOUSFIELD, published in the London *Electrician*, April 15, refers to a cell consisting of an inner porous cup with nitric acid and a carbon pole, and of an outer vessel containing sodium hydrate solution and a metal pole, preferably of zinc. The best results are obtained by using nitric acid of maximum conductivity—namely, a 31 per cent solution—and sodium hydrate of maximum conductivity, or of a strength slightly below this, *i. e.*, a solution of from 12 to 15 per cent. On open circuit an e. m. f. of 2.6 volts may be obtained. It is claimed that the cell "may be short-circuited far longer than most cells before it runs down." The e. m. f.'s are given, if various other metals are substituted for zinc and other acids for nitric acid. Experiments were also made with two carbon poles, instead of using one carbon and one metal pole. "As was to be expected, a considerable e. m. f. was still present. This e. m. f., however, I did not succeed in obtaining very constant; it varied considerably with the carbons used, the extreme e. m. f.s registered being 1.1 and 1.8 volts. The mean e. m. f. worked out from a large number of experiments was 1.35 volts. This is no doubt an example of an e. m. f. which is commonly put down to the difference in velocity of the ions of the respective liquids." (This conclusion is open to strong objections, since the author entirely neglects the reduction and oxidation processes which he necessarily gets in the electrolyte at the inert cathode and anode, respectively. The action in the Becquerel cell, which consists of platinum plates in acid and caustic potash, respectively, and which is cited by the author for sake of comparison, has been completely explained long ago by Ostwald. The following conclusion of the author must therefore also be disputed.) From his results he thinks that the e. m. f. of the cell is made up thus: "e. m. f. due to two liquids in contact 1.35 volts, e. m. f. due to the introduction of soluble zinc pole 0.95 volt, total e. m. f. 2.6 volts."

In an article of *Elektrochem. Zeit.*, April, K. HEINTZ describes another primary cell, without, however, giving the most essential details. The main point he makes is that it is not necessary to remove the consumed depolarizer completely, but only about one-eighth of it, and then substitute for this small part a regenerating solution which brings the depolarizer back to its initial state. The depolarizer is called "nitron;" the electrodes are zinc and carbon.

MISCELLANEOUS.

Benzine Fires.—In chemical cleaning and dyeing works sudden fires have sometimes occurred, starting when the workingman draws the cleaned woollen material out of the bath. Richter has formerly found that in moving the woollen material through the benzine, the latter becomes negatively charged and the wool positively charged, this being simply an example of electricity produced by friction. When the material is taken out of the bath, a spark discharge may take place and the explosive mixture of benzine vapor and air is ignited. This occurs especially at lower temperatures. Richter has found that the addition of a small amount (one-twentieth to one-fiftieth per cent) of oleate of magnesium to benzine prevents such fires. In an investigation, the results of which are published in the *Zeit f. Elektrochemie*, March 25, G. JUST has endeavored to find the explanation of the effect of this addition. He finds that it is due to a considerable increase of the conductivity of pure benzine by the addition. If a vessel, as used for the determinations of conductivities by Kohlrausch's method, is filled with benzine, and one electrode is connected to earth and the other to an electroscope, then, if a charge is impressed upon the latter, it retains it for several minutes. If, however, one-twentieth per cent of oleate of magnesium is added it is nearly impossible to charge the electroscope, the electroscopic charge flowing off immediately through the solution to the earth. He has devised a small apparatus which enables one to find out in chemical dyeing works whether the solution has a proper conductivity to prevent fire. In Fig. 2 A is a small electroscope, which is connected with the electrode B. The second electrode C is earthed. If the space D is filled with a solution to be used in the dyeing works, the electroscope must not retain an electric charge, if the solution is in proper condition.

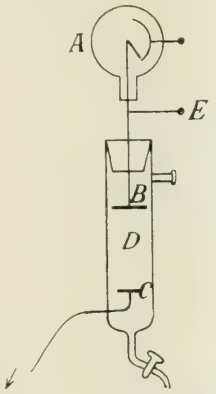


FIG. 2.—TESTING DYEING SOLUTION

Calcites.—The *Lead and Zinc News* of April 4 contains an illustrated article on the crystallography of the calcite of Joplin, by O. C. FARRINGTON.

Organic Products.—A review of the chemical industries of organic products in the United States is given by W. VIEWEG in *Chem. Zeit.*, April 1, on the basis of the reports of the Fifth International Congress for Applied Chemistry, in Berlin.

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

BY GEORGE P. SCHOLL, PH. D.

ELECTRIC FURNACES AND FURNACE PRODUCTS.

Rotatory Electric Tube Furnace.—H. N. Potter, New Rochelle, N. Y. Patent 756,891, April 12, 1904. Application filed November 21, 1901.

This resistance furnace consists essentially of a tube of carbon, lined on the inside and coated on the outside with a layer of fused magnesia. This layer is actually fused to the surface of the carbon tube, by placing the latter in a horizontal position, heating it to a temperature high enough to melt the magnesia and then rotating the tube so as to distribute the molten material evenly over its surface. The apparatus thus prepared is connected as resistance between the poles of an electric circuit. Fig. 1 shows construction whereby the furnace can be rotated and set at any desired angle, to adapt it to

the different characteristics of materials which are introduced at the upper end and have to pass through the tube by their own weight. A furnace of the above construction, having a two-inch bore and a length of one foot, is stated to take over 1000 amperes at five volts. It is proposed to transform this current into one of say five amperes and 1000 volts. For this purpose transformers are mounted together with the tube furnace, in a barrel or on trunnions within a suitable cage, so that the whole combination can be rotated. In operation, current enters the transformers from the line and the secondaries supply the tube with the requisite current. The tube, with its covering of magnesia, is surrounded by a jacket of lime, which, in its turn, is covered by an outer casing tube of tile or Portland cement. The terminal connections are made through split rings of metal, rings of carbon being interposed between the metallic rings and the ends of the tube.

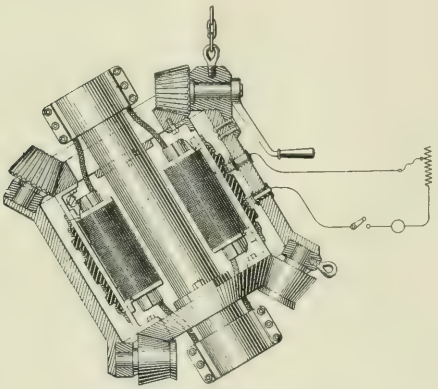


FIG. 1. ROTARY TUBE FURNACE.

Manufacture of Cyanamide Salts.—G. Erlwein, Berlin, Germany. Patent 757,185, April 12, 1904. Application filed August 16, 1902.

The invention relates to the production of cyanamide salts by means of carbon, lime and nitrogen. A mixture of lime and carbon in such proportions as are required for the formation of cyanamide, e. g. 56 CaO and 24C,, is subjected to the action of a high temperature, preferably in an electric furnace. The furnace shown diagrammatically in the specification is of the conventional rectangular, box-like form, with carbon electrodes introduced opposite to each other through the end walls. An outlet pipe for the gases generated during the operation is arranged in the upper part, while an inlet pipe for the nitrogen is shown above the bottom. The mixture of coal and lime is heated in this furnace to about 2000° C., whereas the temperature necessary for previously-formed calcium carbide to combine with nitrogen lies somewhere between 800° and 1000° C. When the above temperature is reached, the nitrogen is sent through the mixture, the rate of speed at which it is introduced being so regulated that it is absorbed as completely as possible. The operation is regarded as complete, when it is found by analysis either of the material or the escaping gases that the nitrogen is no longer absorbed. Instead of charcoal and lime, a mixture of charcoal with calcium carbonate may be employed, or a metal, like iron, might be added to the mixture for the purpose of increasing the conductivity. Not only mixtures containing lime and carbon in the theoretical proportions (56CaO and 24C) may be used, but also a further addition of charcoal or organic materials containing carbon, as sawdust, pitch, tar or the like, may be made to supplement the cyanamide-forming mixture. This diminishes the necessity of great care in operation.

Apparatus and Processes for the Electrolytic Production of Metals and Compounds; Precipitating Metals from Solutions. C. Butters, Berkeley, Cal. Patent 756,211, April 5, 1904. Application filed October 3, 1902.

The invention has particular reference to the electrolytic precipitation of gold and silver from cyanide solutions. The cathodes are sheets of metal, coated with tin, the so-called tin plates of commerce, while the anodes are lead peroxide. They are usually placed three inches apart, and the solution is made to flow between them, preferably in an upward or downward direction, at a uniform velocity. A high current density is used for the purpose of depositing the gold in a loose, slimy form on the tin cathode, so as to be able to brush or wipe the deposit off easily. This operation is usually performed once a day, by running a wiper over the plates while they are in position in the electrolytic tank. The removed slime is allowed to settle on the bottom of the apparatus, and the separation and refining of the metals is carried out in the usual way. In practice a current density of about 0.5 ampere per square foot of cathode is found suitable in most cases. To obtain the most suitable current density at the cathode, the voltage is made to vary with the conductivity of the solution and adjusted until the metal deposits just loosely enough to be wiped off easily. Mr. Butters has been one of the most active pioneers in the field of electrolytic precipitation of gold, first in South Africa, and in more recent years in this country and Mexico. (Concerning the industrial application of this process see the paper by E. M. Hamilton in Electrochemical Industry, April, 1904, page 131.)

Process of Treating Low-Grade Ores and Tailing by Electrolysis.—Ernst Fahrig, Philadelphia. Patent 756,223, April 5, 1904. Application filed May 9, 1903.

The ores and tailings to be treated are first crushed to any desired mesh above 20, and are then introduced into a vat, water and a suitable electrolyte being added, until the quantity of both that has been admitted, amounts to about 60 per cent of the dry ores and tailings, and forms a sufficiently liquid pulp. The latter is then lifted to the top of a square or rectangular tower, the walls of which are provided with a series of inclined sheet copper plates, which serve as cathodes and are sufficiently thick and strong to stand the pressure of the pulp which is passed over them and flows downward from one to the other. Below each cathode is arranged an anode of graphite. The voltage is approximately five to seven volts and the current 0.08 to 0.1 ampere per square foot of cathode. For the electrolytic precipitation of the precious metals two to five volts and a current density of from 0.05 to 0.06 per square foot of cathode surface are preferred. The electrolyte may be any oxychloride or chlorides, or a weak solution of potassium cyande or "hypochlorid." The pulp flows down the tower, and the precious metals are deposited on the cathode plates, while the partially extracted pulp passes into a mercury trap standing on the bottom of the vat in which the pulp was prepared, and overflows into the latter vat, whence it is again pumped up to the top of the tower to be retreated as before. This treatment is repeated for about an hour per ton of ore charged. After the greater quantity of the precious metals is electrolytically deposited, the pulp passes over the riffles of a riffle-trough into a leaching tank, the riffles serving to catch any heavy or coarse material, iron pyrites or concentrates. When the leaching tank is filled by the different charges obtained from the charging vat, the supply of ore to the latter is shut off, whereupon the liquid contained in the leaching tank is passed to the charging vat, thence through the tower, and over the riffles back into the leaching tank again, this treatment being continued until tests show that the precious metals have been sufficiently extracted. Practical tests are stated to have shown that from twelve to eighteen hours of electrolyzing and oxidizing are sufficient for leaving the pulp in the leaching tank for about from ten to twelve hours. To regain the precious metals still contained in the liquid, it is finally

proposed to subject it to filtration or decantation, and to heat the liquor thus obtained to 120° or 130° F., and then "subject it to electrolysis in an electrical depositing or precipitation battery, or both, also charged from the dynamo." The pulp, after a second washing for the last trace of precious metal in solution, is run off as waste.

Recovery of Gold and Silver from Cyanide Solutions.—S. B. Christy, Berkeley, Cal. Patent 756,328, April 5, 1904. Application filed May 20, 1901.

The keynote of this process for the electrolytic deposition of gold and silver from very dilute cyanide solutions is the use of a large current density in order to render bulky apparatus unnecessary. The solution, after filtering and clarifying from sediment, is collected in a large storage tank and then circulated through a suitable electrochemical cell and back again to the storage tank rapidly and repeatedly in such a manner that the solution is brought into intimate contact with anodes and cathodes in rapid alternation. The apparatus is shown in Fig. 2. The anodes and cathodes are arranged alternately.

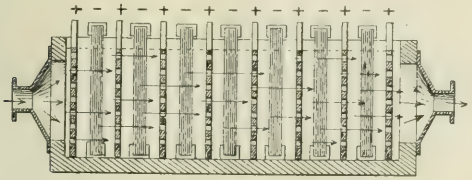


FIG. 2. GOLD PRECIPITATION BOX.

The anodes are pervious to the solution, and may be constructed in the form of wires, rods or gauge, or perforated sheets. The cathodes are also pervious and preferably constructed with a greater precipitating surface than the anodes. No. 24 Birmingham wire gauge iron-wire cloth, 16 meshes per lienar inch, is sufficiently satisfactory, pieces of suitable size being connected electrically in bunches of five or ten by a sheet-iron strip. Instead of iron-wire gauze, metallic filaments or cloth saturated with precipitated silver or gold may be used as cathodes. The velocity of the flow of solution should be such that the potassium cations always find gold solution

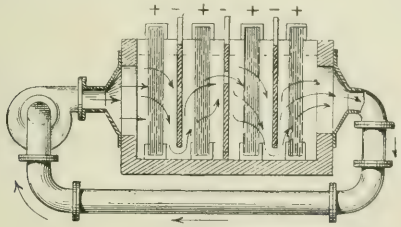


FIG. 3. CLEAN UP BOX.

present to act upon so that gold is deposited without evolution of hydrogen. With a solution containing six ounces silver and gold per ton and voltages of 1.5 to 3.0 volts, a velocity of flow through the precipitation box of one-third of one inch to one inch per second is ordinarily sufficient. A solution is preferably not circulated at a velocity of less than one foot per minute, and the rate of flow is increased in proportion as the gold and silver become exhausted from the solution. It has been possible to precipitate 1000 tons of solution in twenty-four hours in a deposition-box holding only one ton. From 90 to 99 per cent of the precious metals have been recovered, as against 75 or 80 per cent by the old method. The electric current was formerly utilized only to the extent of 5 per cent, and usually not over 1 or 2 per cent, the remainder being wasted, while by the new method the current utilization has gone up to over 80 per cent, with an average ordinarily of from 10 to 20 per cent. The gold and silver deposited by the above method are preferably concentrated in another apparatus, which is shown in Fig. 3. The cyanide solution, which should be as far as possible free from chlorides and sulphates, is forced to flow rapidly through the box E by means of the pump P. The solution passes up and down through the box, and at the same time through the pervious anodes d^3, which are the same electrodes that have previously been used in the precipitation boxes as cathodes, and which carry the deposited precious metals. The sheet iron cathodes are coated with a very thin layer of electroplater's graphite and vaseline before being placed in the box. With an e. m. f. of about ½ volt the gold and silver are rapidly removed from the anodes and deposited on the cathodes, from which they may be pulled off as solid sheets. If zinc precipitation is used instead of electrolytic precipitation, the electric energy is furnished by the zinc in the form of fine granules, shavings or dust. The solution to be treated is forced by a centrifugal pump to circulate from the storage tank through a vessel which contains zinc shavings resting on a filter, and back. The gold and silver are rapidly precipitated by the electrolytic action set up. It is stated that in practice about two ounces of zinc are used to one of gold and silver. The patentee has devoted his attention to the cyanidation process for a number of years, and is well known in connection with the subject.

Apparatus for Electrically Bleaching Materials.—A. A. Vogelsang, Desden, Germany. Patent 756,745, April 5, 1904. Application filed September 21, 1901.

Cotton yarn and other textile materials are bleached in large quantities, from a ton upwards, in such a manner that the material is not moved any more from the time it is placed in the bleaching vat until the bleaching is completed. The complete bleaching plant consists of one tank each for the solutions of salt, sulphuric acid and caustic soda, an electrolyzer, situated so that the salt solution flows to it by gravity, a receiving tank into which the bleach liquor manufactured in the electrolyzer flows, a measuring tank for measuring off definite quantities of liquor, and finally a number of bleaching vats. The bleaching operation is performed by electrolyzing the salt solution in the electrolyzer, a convenient mode of estimating the proper working of the apparatus being to observe the difference of temperature between the inflowing and the outflowing solution, a rise from 12° to 18° C. indicating that the proper strength is attained. The bleach liquor then flows into the receiving tank and is drawn off into the measuring tank ready for use. Meanwhile the material to be treated has been placed in the vats and has been treated with a boiling caustic soda solution, to remove any greasy matters. It is then rinsed with water and the bleach liquor run on, after which the material is rinsed again and scoured with a solution of sulphuric acid, rinsed once more and dried. The electrolyzer belongs to the bipolar type, i. e., to those apparatuses in which only the end electrodes are connected to the source of current, the intervening electrodes being bipolar. The apparatus itself does not present any novel features, but the construction of the electrodes is novel and described in detail. They are illustrated in Fig. 4. The right hand figure shows a cross-section of an intermediate electrode, which is built up of square rods or bars of insulating material, between which

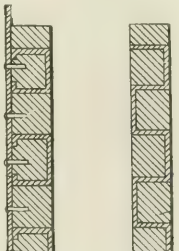


FIG. 4. ELECTRODES FOR BLEACHING PROCESS.

a platinum strip is wound in zig-zag fashion. The end electrode shown at the left-hand is built up similarly, only the current is led to the platinum strips by a lead backing riveted to the insulating bars and extending down one side of the electrode. Several alternative forms of electrodes embodying the same idea are described. To avoid overheating of the electrode, the current density should be about 2 amperes per square millimeter of cross-section, and 50 amperes per square decimeter of electrolyzing surface. The thickness of the platinum foil is greatly exaggerated in the illustrations, as in actual practice foil as thin as 0.03 millimeter may be employed.

Process of Producing Chemical Compound.—John J. Griffin, Washington, D. C. Patent 757,036, April 12, 1904. Application filed January 16, 1902. Renewed September 3, 1902.

The process is based upon the property of metallic carbides to conduct the current like metals and the consequent possibility of utilizing them as electrodes for electrolytic purposes. The gases liberated electrolytically combine with the compounds, which are generated by the chemical action of the above carbides upon the water, and give rise to new chemical products. The electrolytes must be capable of yielding an electrolytic product which will react either on the electrode, solvent, one or both electrodes, or on the product resulting from the direct chemical reaction of the electrolyte on the carbide. As a typical case the electrolysis of dilute sulphuric acid with electrodes of calcium carbide in a diaphragm cell is given. The water of the solution reacts on both electrodes to give acetylene. At the cathode two atoms of hydrogen react on one molecule of acetylene to give ethylene, and four atoms of hydrogen react on one molecule of acetylene to give ethane. The ethylene so produced further reacts on the sulphuric acid in solution to give ethyl sulphuric acid. At the anode two atoms of oxygen react on one molecule of acetylene to give glyoxal, and four atoms of oxygen react on one molecule of acetylene to give oxalic acid. The following is given as a further view of the scope of the invention. Alkaline hyposulphites; ethylene at cathode and thio-glyoxal and other sulphur compounds at anode. Nitric acid and nitrates: ethylene at cathode and cyanic acid and various nitric compounds at anode. Alkaline nitrites and hyponotrites: ethylene and ethane at cathode and cyanic acid and nitro compounds at anode. Hydrochloric, hydrobromic and hydroiodic acids and their salts; ethane, ethylene, and di-iodo-ethane at the cathode, and various halogen addition products of acetylene at the anode. Potassium and sodium hydroxides; ethylene and ethane at the cathode and glyoxal at the anode. Ammonium hydroxide: Alkyl substituted ammonias and cyanides at the cathode and cyanides at the anode. Various addition products in organic solutions are given as follows: Acetic acid and its metallic salts: ethane and ethylene at the cathode and di-methyl-ethylene and tetramethyl-ethane at the anode. Propionic acid and salts: ethylene and ethane at the cathode and ethyl addition products of acetylene at the anode. Higher homologues of the fatty acid series give ethylene and ethane at the cathode and the corresponding alkyl addition products of acetylene at the anode. Salts of aromatic acids give ethylene and ethane at the cathode and aromatic addition products of acetylene at the anode. Aniline and other aromatic bases and their salts give amino and amido substituted ethanes at the cathode and acetylene addition products, corresponding to the anion of the salt used, at the anode. For the production of certain compounds an insoluble substance in a state of fine division may be held in suspension in the electrolyte and may enter into reaction with the electrochemical product. Further details as to the practical carrying out of the various processes are not disclosed in the specification.

Storage Batteries.

Protective Sheath or Envelope for Storage Battery Plates.—Achille Meygret, Paris, France. Patent 756,176, March 29, 1904. Original application filed June 29, 1903. Divided and refiled July 27, 1903.

The plate or grid with the active material on it is covered with a sheath or envelope, in order to prevent the active material from becoming loose and falling down. The protective sheath is obtained by dipping the plate, after the active material has been applied to it, into a bath of castor oil, essence of turpentine, octonitric cellulose, and ordinary nitrate of cellulose of commerce, the tetranitrate of cellulose being preferred. The plate, after having thus received a closely fitting sheath, is then passed between cylinders which cut a series of fine gashes into the sheath, thus allowing the requisite access of electrolyte without destroying the continuity of the protective coating.

Electric Accumulator Plate.—C. P. Elieson, Paris, France. Patent 755,642, March 29, 1904. Application filed October 16, 1903.

The plate described is built up of a number of superimposed thin, flexible strips of lead, which are alternately straight and corrugated. The strips are united at their inner end to guard strips, running along the edge of the plate, while the outer ends are left free. Two of such plates are then placed with their united ends facing each other, and a groove formed on the longitudinal edge of each. A lead tube is then placed in the grooves, and the two sections soldered to the tube. A plate is thus obtained with a hollow rib in the middle, by which means the inventor claims to have in actual manufacture reduced the weight of the plate sometimes as much as 15 per cent.

Process of Making Electric Accumulator Plates.—C. E. Elieson, Paris, France. Patent 755,643, March 29, 1904. Application filed October 16, 1903.

The plate is made by placing alternate straight and corrugated strips of lead with their edges upon a flanged metal tray with guard strips along the longitudinal edges and extending beyond these edges. Similar guard strips are then laid upon the strips and the whole covered by a tray similar to first one. The trays and strips are securely clamped together and the ends of the strips are united by autogenous soldering. A rib of solid metal is thus formed along the two longitudinal sides. The plate is then divided longitudinally in the middle, and the soldered sides turned around to face each other and united by soldering. A plate is thus formed which has a longitudinal rib in the middle, while the strips are free at the edges. Cheap and expeditious production is claimed for such plates.

Storage Battery Grid.—G. W. Frost, Columbus, Ohio. Patent 757,396, April 12, 1904. Application filed February 9, 1904.

The grid of pure lead is shown in Fig. 5; it comprises a frame, a series of retaining strips with a horizontal web, extending to the other face of the plate. The webs taper slightly from the strips to their edges in order to facilitate the removal of the cast grid from the mold. The retaining strips are cast as thin as possible, the usual thickness being 0.06 inch. This thickness is greater than that necessary for rigidity, therefore the cast grids are passed under a milling cutter which removes 0.03 inch from each side of the plate, thereby reducing the thickness of the grid from 0.32 inch to 0.26 inch, and decreasing its weight by one-third. For automobile batteries the grids are cast 0.25 inch thick and milled down to 0.19 inch. Grids

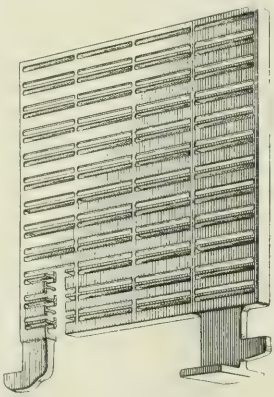


FIG. 5. BATTERY PLATE.

of considerable size are stiffened by ribs. The space available for active material is claimed to amount to from 50 to 70 per cent of the total volume of the electrode.

GALVANIC ELEMENTS.

Battery Cell.—Emerson Whitman, Lynn, Mass. Patent 757,164, April 12, 1904. Application filed July 2, 1903.

A containing vessel of carbon, which serves also as cathode, is corrugated on the inside, and upon the outside glass is applied in a liquid or plastic state, in order to permeate the pores of the carbon, and to prevent leakage of solution through the carbon.

Galvanic Battery.—C. B. Schoenmehl, Waterbury, Conn. Patent 757,355, April 12, 1904. Application filed November 22, 1899.

The cell belongs to the zinc copper oxide type, the essential feature being to provide a receptacle for the copper oxide, widest at the top and narrowing towards the bottom of the containing jar, and to locate the copper oxide in the jar in such a manner that its condition can be always observed.

Dry Battery.—A. F. Swan, Bayonne, N. J., and A. W. Rose, New York. Patent 757,422, April 12, 1904. Application filed July 22, 1903.

The inventors claim the combination of a casing, a negative element and two separate positive elements therein, active material interposed between the negative element and the positive elements, and a switch device and connections whereby the positive elements may be alternately switched into circuit with the negative element, so that each element may be allowed to recuperate while the other is being used. The primary idea has been to get a comparatively large number of cells in the smallest possible space.

ON THE COMBINATION OF A SOLVENT WITH THE IONS.

A highly interesting prelimnary paper by Dr. T. LIVINGSTON R. MORGAN and C. W. KANOLT was presented on April 8, before the New York Section of the American Chemical Society. The following paper will be published in the *Journal of the American Chemical Society* and the *Zeitschrift für Physikalische Chemie*. In the following we give a brief abstract of the paper.

Preliminary experiments show that by electrolyzing a solution of silver nitrate and pyridine in water, that pyridine migrates with the silver and increases in concentration at the cathode, while it decreases at the anode. With cupric nitrate and water, dissolved in alcohol, the water migrates with the copper ions and increases at the cathode and decreases at the anode. This indicates the presence in solutions of combinations of ions with the solvent to form complex ions which break up at the electrodes. The results show only, however, the difference in the amounts of solvent carried by the positive and negative ions.

The application of the law of mass action to one possible equilibrium shows that Van't Hoff's form of Rudolphi's empirical dilution law can be readily derived. Thus, if MA is the salt, and S the solvent, we have

$$2MA + (x + 2y + z)S = (M_2.xS)^{++} + 2(A.yS)^{-} + zS$$

and if Cs is the undissociated concentration; Ci that of one of the ions and z large compared to x and y, it follows that

$$\frac{Ci(2Ci)^2}{Cs^2} = 4\frac{Ci^3}{Cs^2} = \text{constant}.$$

The authors call attention to the fact that in this way it is easy to account for the variation in the speed of migration of the ions with the dilution; the presence of solvent of crystallization, and the variation in the value of n in the general empirical dilution law $\frac{Ci^n}{Cs} = \text{constant}$. It is observed that this takes nothing away from the ionic theory, but, in fact, conditions only those portions of that theory which have hitherto failed to hold.

Correspondence.

ELECTROLYTIC AND ZINC PRECIPITATION OF GOLD FROM CYANIDE SOLUTIONS.

TO THE EDITOR OF ELECTROCHEMICAL INDUSTRY:

Sir—With regard to the article on electrometallurgy in gold, published in the February issue of ELECTROCHEMICAL INDUSTRY, I may say that there is a great deal of interest in the development of this process since I left South Africa, and that it is now an up-to-date process in every sense. The electrolytic and the zinc processes are combined together and now used in our best plants, the electrolytic process being used to clean the solution and taking out from 90 to 93 or 94 per cent of all the products and abstracting practically all of the copper. About 8 or 9 per cent of the electric box capacity is filled with zinc, to which the electric current is also added. This is used for taking out the last few per cents of gold and silver. At our works in Salvador we make an extraction of about 99 per cent of the values in the solution on regular monthly runs, and by this combination the zinc is constantly at its best, as everything that would spoil the surface of the zinc as a precipitating surface has been eliminated by going through the electrolytic precipitation first.

At present we run the electrolytic process in three plants in this country; Virginia City, Minas Prietas, in Mexico and at Butters Salvador Mines in Salvador. All these plants have introduced small zinc additions electrically connected with the precipitation boxes. This gives us a very complete precipitation process.

CHARLES BUTTERS.

San Francisco, Cal.

FERRO-NICKEL FROM PYRRHOTITE.

TO THE EDITOR OF ELECTROCHEMICAL INDUSTRY:

Sir—On page 154 in the April issue of the ELECTROCHEMICAL INDUSTRY there appears a synopsis of my article in the *Iron Age* of February 18, on "Ferronickel Direct from Pyrrhotite," and the attention is directed to a misprint, which I hereby wish to correct, namely, regarding the power used in the experiments referred to, the same being 1350 amperes and 80 volts, instead of the 135 amperes and 80 volts given.

ERNST A. SJÖSTEDT.

Sault Ste. Marie, Ont.

ARSENIC IN COPPER REFINING.

TO THE EDITOR OF ELECTROCHEMICAL INDUSTRY:

Sir—In the April issue of your paper I note that Mr. L. Webster Wickes makes, in reference to a paper of mine about the sliming of arsenic oxide in "metallic electrolytic dissolution," certain statements which call for some explanation on my part.

The cases stated by Mr. Wickes are, of course, entirely different from the commercial electrolysis of copper or nickel where the percentage of arsenic has been reduced to a very small limit by the ordinary fire metallurgical methods. There is, however, not much doubt to my mind that the oxides of arsenic, antimony, etc., present in the anodes, pass into the slimes directly, but are slowly dissolved from the slimes by purely chemical action. This redissolution will occur even in an electrolyte very near the neutral point.

Naturally the fact that arsenic is more electropositive than copper, and that its cations are present in such small numbers in comparison with the copper cations makes it clear that provided the proper electrode-voltage is not exceeded, arsenic is

codeposited with copper in only infinitesimal amounts. This explains satisfactorily the facts given in the last two paragraphs of Mr. Wickes' article, and also brings out the point raised by me on several occasions, namely, the importance of knowing the sliming effects of different metalloids present in a metallic anode as conditioned upon the various physical, chemical and electrochemical states.

Woolsey McA. Johnson.

La Harpe, Kansas.

Book Reviews.

Electrolytic Preparations, exercises for use in the laboratory by chemists and electrochemists: by Dr. Karl Elbs. Translated from the German by R. S. Hutton, M. Sc. New York: Longmans, Green & Co. 12 mo., 100 pages. Price $1.60.

Our friend, the translator, lecturer on electro-chemistry at Owens College, Manchester, England, is doing yeoman's work for the cause of electrochemistry in many directions, but has done no one thing of more use to English-speaking students than the translating of Dr. Elbs' laboratory guide. Professor Elbs is well known as a prominent representative of modern electrochemistry in Germany, and has been successful both in original research work and as a teacher. An outcome of his activity as university teacher is his laboratory guide. The only shortcoming of the book is its brevity, for after perusing the twenty-nine pages devoted to inorganic preparations, and noting the fifty pages following dealing with organic compounds, the conviction is strong upon us that there is not only room, but a crying need for such an enlargement of the work as would furnish a full 100 pages to each of these departments. As it is, the experiments in inorganic chemistry are certainly too few, and, if measurements of current output are made, are too fragmentary to illustrate all of the fundamental laws of electrolysis and consequent formation of chemical compounds. Brevity is, after all, one of the least blameworthy, and most easily remedied, shortcomings for which an author can be criticised.

CARBON BRUSHES FOR DYNAMOS.

That the use of carbon brushes (instead of the metallic brushes which were first exclusively used) has greatly simplified the solution of one of the most important problems in dynamo design—namely, to insure good commutation—is a fact now fully recognized by all electrical engineers. It is also recognized that in order to obtain the best results, a kind of carbon should be used which is specially adapted to the particular conditions in each case. In view of the very powerful currents generally used in electrolytic works, good commutation is a matter of great importance in such works.

The brush made by the Le Valley Vitæ Carbon Brush Co. was the first introduced on the market as a permanently self-lubricating brush; it requires no attention, since it constantly lubricates the commutator without gumming. On account of the quality of carbon used for this brush, the following special features are claimed for it. It throws off no carbon dust, thus obviating one of the prime causes of short-circuiting, particularly on enclosed motors. It does not cut or scratch the commutator, so that no sandpapering or turning down is required; the brush, therefore, has itself a long life, and also lengthens the life of the commutator. It has a much lower resistance and gives better contact than ordinary carbon; it is claimed to carry at least 100 per cent more load than brushes made of ordinary carbon.

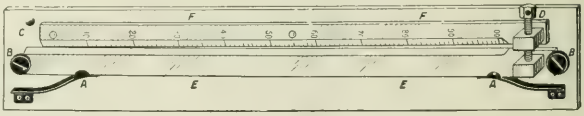
Different grades of carbon are used according to the special conditions under which the machine has to work—especially whether the brushes are to be used on a stationary machine or on railway car motors. For ordinary use three different grades are made, being designated as hard, medium, and soft, while for heavily overloaded machines, sudden and extreme change in load, and for hot commutators, as well as for special traction service, special grades of carbon are furnished. The Vitæ carbon brushes are furnished in all the various sizes needed in practice, and the Vitæ generator brush material, regular or special grade, can be had in plates 13 x 9 inches, of any thickness, or strips 12 inches long and of any width up to 4 inches, and of any thickness. These plates, or strips, can be cut with an ordinary hack-saw or emery wheel, to any size required.

THE MEASUREMENT OF GOLD AND SILVER BUTTONS IN QUANTITATIVE BLOWPIPE ANALYSIS.

The quantitative blowpipe assay for gold and silver was invented by Harcourt, a student of Freiberg, in 1824. Instead of weighing the very small buttons obtained he measured their size on a scale which he had constructed empirically by drawing two fine slightly deferring lines on white cardboard and placing buttons of known gold or silver content between the lines at points where they fitted, and marking opposite those points the corresponding content of the ore. The method was further developed by Prof. Plattner, who constructed the well-known button scale ruled on ivory. To fix the dimensions of the scale, he assayed very rich silver ore repeatedly in the muffle until it was known with certainty to contain exactly 3.4 per cent of silver. He then made repeated blowpipe assays of this ore, obtaining buttons very close together in size and weight. Two lines were then drawn on ivory, so that they deferred approximately the diameter of these buttons in a length of 150 mm. The scale was then divided into equal divisions, and the silver content corresponding to each division calculated on the assumption that the buttons are nearly spheres, so that their weights vary as the cubes of their respective horizontal diameters.

Prof. V. Goldschmidt, of Heidelberg, later proposed two improvements, the first being to remelt the cupelled buttons on charcoal, and the second to measure the horizontal diameter of such remelted buttons under the microscope. The diameter being determined, reference to a previously constructed table, the design of which is based on an ingenious plan, gives the volume and weight of the button, when of gold or silver.

Dr. J. W. Richards, of Bethlehem, Pa., has adopted Goldschmidt's idea of remelting the button on charcoal wherever practicable, but has devised a modification of Harcourt's method for measuring the buttons. His method is described by him in a paper, published in the Journal of the American Chemical Society, vol. 23, No. 4, April, 1901, page 203. In this paper a



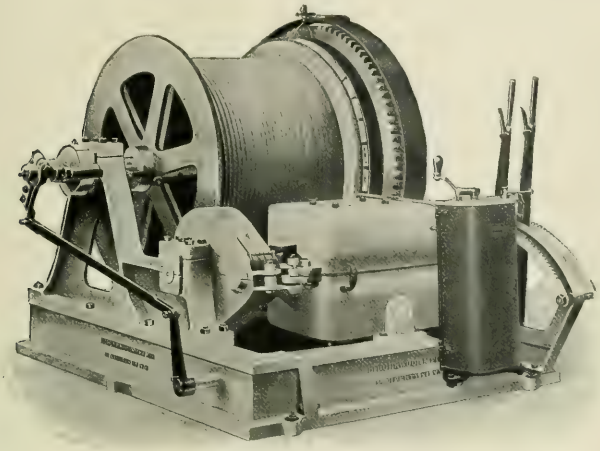
concise and complete review of the different methods available to the blowpipe assayer is given, and the reader, interested in the subject, may be referred to it. In the following we give a description of Dr. Richards' scale.

The idea is to make two metallic edges perfectly straight, lying on a flat surface and held apart at the other extremity by a set screw, so that the point 100 may indicate a fixed width or separation of almost exactly 1 mm. In reality the button whose horizontal diameter fits at 100, has a diameter of 1.02 mm., but this distance has been so chosen that the volume, and, consequently, the weight of said button are exactly that of a perfect sphere whose diameter is 1 mm. The other numbers

on the scale have the same significance. For example, the button whose horizontal diameter fits at 43.5, has the volume and weight of a sphere whose diameter is 43.5 hundredths of a millimeter and such is the basis on which the table is calculated.

In using the scale the button is put into the groove, the scale inclined slightly, and tapped until the button wedges itself. The tenths of a division are estimated, taking the points where the sides of the button touch the scale as the reading. As the button may sometimes roll with its shorter vertical diameter across this scale, several readings are taken, and the highest reading, occurring with regularity is the true horizontal diameter. For instance, among 43.4, 43.4, 41.6, 43.5, 41.8 and 43.5 it is evident that 43.5 is the horizontal diameter and the 41.6 or 41.8 the vertical. The button can also be observed under the lens to see how it is lying at any given reading

A gentle spring keeps the right-hand strip against the set screw, thus allowing it to be pressed back for cleaning out the slot with a brush or removing a button. The scale is made of hardened aluminium for lightness, and is set in a velvet-lined leather case. It is made by Messrs. Williams, Brown & Earle, of Philadelphia.



ELECTRIC MINING HOIST.

DIRECT CURRENT ELECTRIC MINING HOIST.

Mine superintendents and metallurgical engineers generally will be interested in the electric hoists illustrated in the adjoining engraving, which shows the latest pattern of a direct-current electric mining hoist, with patent friction drum and brake, built by the Lidgerwood Manufacturing Company, 96 Liberty Street, New York City. This hoist is designed for use with direct current of 500 or 250 volts, and embodies in its construction the various features which are characteristic of all Lidgerwood hoists, and which have gained them wide acknowledgment as the standard type of modern high-speed hoisting engine.

Briefly, there is the usual pleasing simplicity in design with few parts, and compactness in construction, giving great strength and insuring the highest efficiency and durability in service. The drum motor and controller are mounted complete on a bed-plate. The resistance boxes are usually separate from the hoist, being conveniently located so that the heat generated may not be annoying to the operator. In smaller sizes it is sometimes desired to have the machine completely self-contained and portable, in which case the resistances are of special form, and attached to the inside of the bed-plate.

The friction drum is of the standard Lidgerwood form, equipped with all the latest patented improvements. The motor, which is made by the General Electric Company, is of the armored type and especially adapted for hoisting purposes. All the moving parts are protected from dust and moisture by suitable casing, and the gearing from the motor to intermediate shaft is cut, and enclosed in an oil-tight gear case.

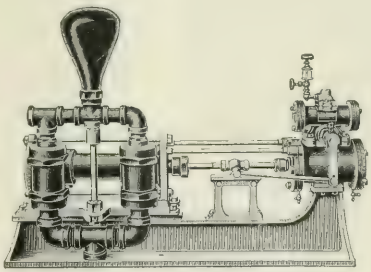
The drum gearing is cast from standard patterns and is protected by means of the usual guard band. The controller, which is of the railway type, is provided with a reversing switch, and mounted so as to be most convenient to the operator.

The friction and brake levers are mounted in a rack with notched quadrants and are fitted with thumb-latches. A large number of these electric mining hoists have been built, and have given, in every instance, complete satisfaction.

ACID PUMPS.

One of the greatest difficulties met with by the manufacturers of acids is the destructive action of the liquids upon the metal piping and pumps of their plants. This has been overcome by the substitution of hard rubber, of which not alone pipings and fittings, but pumps and all kinds of utensils are now successfully made, for conveying acids, chemicals, dyes, brine, etc.

The leading chemical manufacturers and dye works of this country have been quick to recognize the advantages of this material and to adopt it for their use. It is manufactured by the American Hard Rubber Co., an illustration of a hard rubber pump being given in the adjoining figure. The American Hard Rubber Co. is exhibiting their products at the St. Louis Exposition, Liberal Arts Building, aisles 7-H and invite inspection of their pumps operated by hand, steam or electricity.



HARD RUBBER PUMP.

Union Engineering Building.—In order to enable the American Society of Mechanical Engineers, and the American Institutes of Electrical Engineers and of Mining Engineers, to avail themselves of Mr. Carnegie's gift of a building for headquarters and library purposes, etc., the conference committee has had drafted a bill incorporating what is known as the United Engineering Society to hold the property for the societies. This bill was introduced in the State Senate by Senator Townsend, of Utica, and has already passed both the chambers, and has gone to the Governor for signature. The bill is virtually a transcription of the act incorporating the Cooper Union.

INDUSTRIAL NOTES

We have received from the Whitall Tatum Co., of Philadelphia and New York, their 1904 price list of chemists' glassware and sundries. Besides their regular qualities of flint and green glass, they make amber blue, dark green and white opaque glass.

Messrs. Richard C. Remmey & Son, the well-known chemical stoneware manufacturers, of Philadelphia, announce that they have admitted Mr. John B. Remmey as a partner, and that their business will be continued in future as Richard C. Remmey & Sons.

We have received from Messrs. Merck & Co. of New York, their little pamphlet with the title "Merck's Reagents," conforming to the standard laid down in Dr. Krauch's "Testing of Chemical Reagents." The pamphlet contains a concise list of the different reagents and their uses.

The Westinghouse Machine Company, of Pittsburgh, has just issued an interesting and neatly illustrated pamphlet on the Westinghouse-Parsons Steam Turbine. In view of the importance of any new advances made in the generation of power for electrochemical and metallurgical works, we will return to this subject in a later issue.

Refractory Brick.—The Harbinson-Walker Co., of Pittsburgh, has issued a catalogue containing a large amount of very useful information in connection with the use of silica, magnesia, chrome and fire-clay brick and various refractories, with other tables of use for metallurgists. The illustrations and furnace drawings are very neat, and print and mechanical make-up are excellent. The catalogue is bound in red morocco.

Platinum.—Platinum and its allied metals, which depend almost entirely upon the Ural Mountains for their crude supply, have already felt very decided results of the Russian-Japanese war, owing to heavy withdrawals of forces from this mountain district by the Russian Government, the effect of which has naturally caused an advance in current rates. For some time there has been an increasing demand for platinum and its alloys in the electrical and chemical fields, which is constantly being supplemented by the increasing use of gas engines, automobiles, and various new electrical appliances, having platinum contacts and attachments. This growing demand, with doubtless a long continuance of the present situation in Russia, would strongly point to a further advance in a very short time.

PERSONAL.

Mr Frank Kleetko, the well-known copper expert and consulting engineer, announces the removal of his offices to 307 Battery Park Building, 24 State Street, New York.

Wilhelm Hittorf, Professor of Physics and Chemistry in Muenster, Germany, celebrated his eightieth birthday on March 27. He has especially distinguished himself by his very careful and extended investigations of the transport numbers of the ions in aqueous solutions. These researches were begun by him in 1853, but the importance of his investigations were not recognized before the end of the seventies.

DIGEST OF U. S. PATENTS

Prior to July, 1902.

Compiled by Byrnes & Townsend, Patent Lawyers, National Union Building, Washington, D. C.

Chemicals.

The following patent should be inserted on page 124, March issue, where it had been omitted by mistake.

700,671. May 20, 1902. Max Buchner, Mannheim, Germany. Reduces azo compounds dissolved or suspended in an electrolyte in the presence of tin.

Example 1.—Reduction of para-amido-azo-benzol to paraphenylenediamine. Anode.

Anode, lead. Anode solution, 10 per cent sulphuric acid. Cathode solution, "a mixture consisting of 48.7 parts, by weight, of chloride of para-amido-azo-benzol, five grams of powdered electrolytically-precipitated tin dissolved or suspended in one hundred parts, by volume, of water, and two hundred and fifty parts, by volume, of fuming hydrochloric acid." Current density 300 to 400 amperes per square meter. Temperature, 60° C. "The resulting paraphenylenediamine is precipitated in the form of a chloride by saturating the cathode electrolyte with hydrochloric-acid gas in the cold, the anilin, which is produced at the same time, remaining in solution.

Example 2.—Reduction of orange II. to amido-beta-naphtol.

Anode solution, 10 per cent sulphuric acid. Cathode solution, thirty-two parts of orange II., two hundred and fifty parts of water, and two hundred and fifty parts of fuming hydrochloric acid.

The Production of Aluminum from Molten Electrolytes.

(Continued from Page 166.)

476,914. June 14, 1892. Myrthil Bernard and Ernest Bernard, Paris, France.

Electrolyzes a molten mixture of cryolite and sodium chloride, in proportions giving a bath which is lighter than aluminium, *e. g.*, aluminium fluoride, 35 parts, sodium fluoride, 10 parts, and sodium chloride, 55 parts. To produce pure aluminium: The vessel consists of metal set in fire-brick. The anode and cathode are vertical carbon rods, the cathode resting below in a small crucible of cast alumina or calcium fluoride, placed on a cast plate of the same material, which rests on the bottom of the vessel. A high resistance shunt from the cathode terminal to the vessel makes the latter a supplementary cathode, from 5 to 10 per cent of the current passing from the anode to the vessel and coating its wall with a thin protecting lining of an aluminium alloy. The pure aluminium deposited on the cathode rod runs down into the crucible. To produce alloys: Employs a cathode vessel of the alloying metal, having an inclined bottom with tap-hole, set in fire-brick. The aluminium deposited on the vessel forms a fusible alloy therewith which melts and runs down to the tap-hole. May increase the percentage of the alloying metal by using an anode of this metal instead of one of carbon.

503,929, August 22, 1893, Joseph B. Hall, Wheeling, W. Va.

Electrolyzes alumina dissolved in a fused mixture of aluminium chloride, sodium chloride and lithium chloride. May supply alumina by using an anode of mixed carbon and alumina, or may feed the alumina in, stirring it mechanically. Cathode vessel of carbon or mixed carbon and alumina, encased in iron. To produce aluminium bronze, maintains a layer of molten copper in the bottom of the vessel.

512,801, January 16, 1894, Willard E. Case, Auburn, N. Y.

Combines solutions of commercial aluminium sulphate and calcium fluoride to form an "aluminium fluor-sulphate solution." Adds ammonia or fixed caustic alkali to precipitate any iron present as an impurity, removes the iron and adds more caustic to precipitate the desired white aluminium compound, which is removed, fused and electrolyzed, preferably with an initial addition of cryolite to increase fusibility.

512,802, January 16, 1894, Willard E. Case, Auburn, N. Y.

Adds calcium fluoride to a solution of crude aluminium sulphate to form an "aluminium fluor-sulphate solution." Adds an alkali carbonate, e. g., sodium carbonate, to precipitate any iron present as an impurity, removes the iron and adds more carbonate to precipitate the desired white aluminium compound, which is removed, fused, preferably with an addition of cryolite as a flux, and electrolyzed.

Electrochemical Industry

VOL. II. NEW YORK, JUNE 1, 1904. No. 6.

Electrochemical Industry

Published on the first of each month by the
ELECTROCHEMICAL PUBLISHING COMPANY,
[*Incorporated.*]
114-118 LIBERTY STREET, NEW YORK.

J. W. RICHARDS, PH. D. .....*President.*
E. F. ROEBER, PH. D. .....*Editor.*

Telephone Call: 7607 Cortlandt.

Subscription Price: $2 per year, postpaid to any part of the world. Single copies 25 cents.

ADVERTISING RATES GIVEN ON APPLICATION.

Copyrighted, 1904, by the Electrochemical Publishing Co.

Entered as Second-Class Matter, June, 1903, at the Post-Office at New York, N. Y., under the Act of Congress, March 3, 1879.

CONTENTS.

Editorial 211
International Electrical Congress..... 214
The Metallurgy of Gold on the Rand Gold Fields. By Clement Dixon and M. Torrente 215
Electrolytic Refining of Gold. By Emil Wohlwill..... 221
Analysis of Refined Copper. By L. Addicks..... 224
Studies on the Siemens Process for Winning Copper. By M. DeK. Thompson, Jr. 225
Wet Methods of Extracting Copper. By C. H. Jones..... 232
Palladium 234
Recent Metallurgical Patents..... 235
Analysis of Current Electrochemical Patents. By George P. Scholl. 236
Synopsis of Articles in Other Journals..... 243
Current Notes 249
Faraday Society Meeting 249
Correspondence: Electrochemical Notation 251
Book Reviews 251
Two Stories of Zinc..... 252
Electrolytic Interrupter 252
Sulphur Furnace 253
Personal 253
Industrial Notes 253
Digest of United States Patents Prior to July, 1902. By Byrnes & Townsend. (Production of Aluminium from Fused Electrolytes). 253

THE METALLURGY OF GOLD ON THE RAND.

In this issue we publish an article by Messrs. C. Dixon and M. Torrente which our readers will find to be one of the most valuable and important contributions to the literature on the metallurgy of gold on the Rand. It is a very concise and lucid exposition of the development of the cyanide process in that classical country of gold metallurgy, written by two men who have actively participated in its development. Mr. Dixon is a member of the Council of the Chemical, Metallurgical and Mining Society of South Africa, while Mr. Torrente has been most intimately connected with the development of the electrolytic precipitation process during recent years. This makes the statements of the authors authoritative. On the other hand, with respect to that special problem which is of particular interest to our readers—the question of electrolytic precipitation versus zinc precipitation—the exposition of the authors will be found most interesting and impartial. In the statement of facts the article corrects two misconceptions which have repeatedly found expression. First, we refer to a statement recently made by a strong and able advocate of zinc precipitation; this statement, made in one of our contemporaries, was to the effect that electrolytic precipitation is now out of the race in South Africa. Surely, a process by which, during the last year, 239,385 tons of sands or tailings, and 129,137 tons of slimes were treated, with a total production of 72,164 ounces of gold, cannot be considered as dead. Secondly, the Andreoli process, instead of having superseded the Siemens & Halske process, as has been stated repeatedly, has failed in practice to improve matters with the working solutions on the Rand.

The history of gold metallurgy is a good example of the general rule that chemical methods are only resorted to after purely mechanical methods of treatment and concentration have spoken the last word. As long as placer mining pays well, the miner will not care for the application of chemistry for winning gold. But in every branch of metallurgy there comes a time when the miner realizes that he must do something more than apply his old mechanical methods of concentration. He will then try chemical methods, and more than once in the history of metallurgy the whole aspect of an industry has been revolutionized by the introduction of a chemical method. This is what the cyanide process has done for the Rand gold fields, since it enabled many low-grade propositions that could otherwise never have been worked at all to pay handsome dividends. And again, the average chemical engineer of the past did not resort to electrochemical means, unless he was forced to do, in order to accomplish a certain special end. In gold metallurgy it was the necessity to precipitate the gold from very dilute cyanide solutions which led to electrolytic precipitation; and the

merits of the electrolytic process are not impaired by the fact that it later has become possible to use a modified form of zinc precipitation for the same purpose. While thus chemical methods come after purely mechanical methods and electrochemical methods after purely chemical methods in a metallurgical industry, it would be absolutely wrong to believe that the later methods supersede the older ones completely; that the chemist supersedes the mechanical engineer, and the electrochemist supersedes the chemist. This is not the case; what happens is that the chemist and electrochemist combine their knowledge with that of the mechanical engineer, to lead a process of metallurgical treatment to greater perfection. This is quite evident from the article of Messrs. Clement and Torrente. Much of the progress made in the cyanide process in recent years in South Africa has been due to the invention of labor-saving apparatus and, in general, to the fact that the mechanical devices used in the process were brought to a high state of perfection. As Mr. Herreshoff emphasized in a paper published in our last issue, the keynote of progress in chemical engineering is that a chemical engineer shall not be a chemist pure and simple, but shall have had a sound training in mechanical engineering. To insure that the desired chemical or electrochemical reaction takes place, he must have the materials to be treated in the right conditions—in the right shape, at the right temperature, etc.—and for working continuously and on a large scale, this requires a good, sound knowledge of mechanical engineering.

The development of the cyanide process shows that competition is a good thing, that it stimulates a healthy rivalry. It is certainly due to the rivalry between the advocates of zinc precipitation and electrolytic precipitation that both processes were continually modified and improved. The history of gold in South Africa also shows that from a business point of view —and this is the only correct one for judging an engineering enterprise—the better process is not necessarily the one which is technically more perfect. Other considerations may be of greater importance. Thus, in 1894, the advantages were in favor of the electrolytic process, for which royalty of 2 per cent was charged, against 10 per cent royalty for the McArthur-Forrest process. Then the McArthur-Forrest patents were upset, the 10 per cent royalty were no longer a factor in the case, and the advantages were in favor of zinc precipitation. It is only fair to say that at present zinc precipitation seems technically more perfect than electrolytic precipitation; the main disadvantage of the latter is that the solutions leaving the boxes always carry from 0.5 to 1 dwt. of gold per ton, and that it has so far been impossible to reduce this minimum. On the other hand, it is also fair to state that zinc precipitation in the improved form now used on the Rand—*i. e.*, the zinc-lead couple—is distinctly an electrochemical phenomenon; the essential difference in the physics of the processes is that with electrolytic precipitation the electric current is sent through the boxes from an external source, while with the zinc-lead couple we have in the box itself very numerous little galvanic couples or short-circuited galvanic cells, which generate the current, with zinc as anode and lead as cathode. The decisive point which marked the most important improvement of zinc precipitation—Betty's method of adding free cyanide solution at the head of the precipitation boxes—is also quite analogous to a trick often applied in electrolysis by electrolytic refiners or electroplaters who, in order to keep their anodes bright, add free acid to the bath; Dr. Wohlwill's article on gold refining, published in this issue, may be cited as an example.

EFFICIENCY

To operate a process with a high efficiency is the keynote of every engineering success. But what is meant by efficiency? This term is used in different cases in a different sense, and it would be well if an author would always state exactly what kind of efficiency he means. In any case, if one speaks of efficiency, one compares the quantity of something that is put into the operation of a process, with the quantity which one gets out of it. In electrolytic processes we may compare the quantity of electric current—measured in coulombs or ampere-seconds; or, what seems more feasible in engineering work, measured in ampere-hours—with the quantity of the material which is reduced at the cathode or oxidized at the anode. Between both quantities there is a strict proportionality according to Faraday's law, which may be considered as exactly correct, and the factors by which one quantity, *e. g.*, the number of ampere-hours, must be multiplied in order to get the other quantity, *i. e.*, the grams, are well known. For example, we know that in electrolysis of a monovalent copper salt one ampere-hour deposits 2.37 grams of metallic copper, according to Faraday's law. We call this the theoretical figure, because we make the silent supposition that the only reaction which occurs at the cathode during electrolysis is the reduction of monovalent copper ions to metallic copper. In practice, however, it is not often that we have to do simply with one reaction. What takes place in practice is generally a complex reaction. For instance, in our example of copper deposition, we may have, simultaneously with the reduction of the cuprous ions, an evolution of hydrogen. Since we want to get metallic copper, we consider the ampere-hours spent for the evolution of hydrogen as wasted. We compare the amount of copper which we really get with the amount of copper which we should get according to Faraday's law, and by expressing the former in per cent of the latter, we speak of the ampere-hour efficiency of an electrolytic process. This ampere-hour efficiency is necessarily always below 100 per cent, since 100 per cent corresponds to the ideal condition that only the one desired reaction really occurs.

The calculation of the ampere-hour efficiency is of great value for the thorough understanding of the working of an electrolytic process, because this figure tells us to which degree the one reaction which we desire to obtain really goes on. But the ampere-hour efficiency is not of direct practical value, since what the operator of an electrolytic process has to pay for is not the ampere-hours consumed, but the watt-hours consumed. He is therefore more interested to know to which degree the electrical energy which is consumed is utilized for the production of the chemical effect he desires to obtain. For this purpose we have the watt-hour efficiency, which is the quantity of material which we really get, in per cent of the theoretical quantity which we should get, if the electrical energy was completely changed into chemical energy, and used for nothing but the one effect which we want to obtain. While the am-

pere-hour efficiency is essentially applicable to electrolytic processes only, the term watt-hour efficiency can be applied to any electrical process, and therefore comprises in electrochemistry not only electrolytic, but also furnace processes. In the ratio representing the watt-hour efficiency there is again a "theoretical" figure. This theoretical figure is generally based on the assumption that in the process under discussion we have to do with two kinds of energy only, viz., electrical energy, which is consumed, and chemical energy, which is produced. This method of calculating the watt-hour efficiency is open to theoretical objections for the reason that in practice heat energy enters into every electrochemical process. For this reason, the watt-hour efficiency, although nearly always below 100 per cent, may become higher than 100 per cent. This will be the case in such processes in which not only electrical energy is consumed, but also heat obsorbed from the surroundings, to produce the desired chemical effect. From a theoretical point of view, it would be preferable if we would not base our calculation on the thermochemical value of the heat of reaction, but on Helmholtz's "free energy" of the reaction. For a longer discussion of this point, we may refer to an editorial in our January issue

As long as we consider an electrochemical process by itself, the figures for ampere-hour efficiency and watt-hour efficiency give us important information on the working of the process. In an electrochemical laboratory it will always be the highest aim of the experimenter to get as high an ampere-hour efficiency as possible. In practice, however, an electrochemical process is only one step in the whole manufacturing operation, and what is most important here is to get as high a financial efficiency as possible. Financial efficiency is the selling price of the products in per cent of the money to be put into the process. In practice on a large scale, it may not pay, under certain circumstances, to get a very high ampere-hour efficiency or watt-hour efficiency, if this can be obtained only by special attendance or handling of the materials. A reaction with a very low watt-hour efficiency may be a practical or financial success; lighting with electric incandescent lamps is an example. As long as the cost of power is the most important item on the expense sheet of a process, a high watt-hour efficiency is evidently of the greatest importance; but it is equally clear that it should not be obtained by means which introduce new items of expense in the cost sheet, if they are greater than the saving in power.

PLATINUM RECOVERED FROM GOLD.

Electrochemical methods in their application to metallurgy have proven most successful in the latest stage of metallurgical treatment, when the problem is to get a very pure—and for this reason a relatively high-priced—product from materials which have already undergone previous metallurgical treatment and purification. In this way the electrolytic refining of copper and nickel has been specially successful. Electrolytic copper refining methods not only yield very pure copper, but they also enable us to recover the precious metals contained in the copper. The copper refineries of this country produced in 1902, besides 279,000 tons of electrolytic copper, 27,000,000 ounces of silver and 346,020 ounces of gold. For parting the gold from the silver, electrolytic methods have also proven successful, and the same is the case with the final problem to refine the gold and recover its valuable impurities, like platinum.

The Wohlwill electrolytic process of gold refining is in successful use in the Philadelphia Mint, and our January issue of 1903 contained a very interesting description by Dr. Tuttle of the process, as operated in Philadelphia. We are pleased to publish in this issue the first of two articles by the inventor, Dr. Wohlwill, in which the author emphasizes the great simplicity of recovering platinum, iridium, etc., which apparently always occur in Nature together with gold and silver. Dr. Wohlwill's notes deserve the most careful consideration of the metallurgists of this country.

COPPER PRODUCTION FROM THE ORES

In this issue we publish two interesting articles on the production of copper from the ores. In one of them, Mr. Charles H. Jones describes at some detail the methods which are in use at Rio Tinto in Spain for leaching and extracting copper. While the formulæ by which the author of the paper represents the reactions may be open to discussion, his very full description of the actual work of the process on a large scale should be of great interest, since much of the information published before on this subject has become obsolete in the meanwhile. The process is in no way electrochemical in the sense that electrical energy is expended from an external source; on the other hand, a complete understanding of the reactions can only be obtained from the point of view of an electrochemist who sees electrochemical phenomena going on without the expense of external electrical energy, whenever there are metallic materials in contact with liquids representing short-circuited galvanic cells.

A very interesting paper by Dr. M. DeK. Thompson, Jr., also published in this issue, refers to the Siemens electrolytic process for winning copper from the ores. This process is of great historical interest, since it was probably one of the very first ever proposed in metallurgy for winning metal from the ores by electrolytic means. As far as we know, the process has never been used on a large scale, nor has any exact information been published about the operation of the process. Mr. Thompson's paper is most valuable, since it gives the results of a very careful and extended laboratory research on the working of the process. In this respect the information given in the paper appears to be complete, and should be of value to copper metallurgists, although they may not be interested in the Siemens process. The paper does not enable one to draw any conclusion concerning the reasons why the Siemens process has not been a commercial success, but this does not diminish the value of the paper. A laboratory investigation is different from an operation on a commercial scale. In commercial practice in the laboratory one works on a test-tube scale, and it is easy to provide the proper conditions for the desired electrochemical reaction. On the other hand, in metallurgical practice on a large scale, the problems of handling the materials, of putting them into the correct condition for starting the reaction and—last, not least—maintaining the materials in proper condition during continuous operation, are often most difficult, and, what counts more in practice, are often very expensive.

INTERNATIONAL ELECTRICAL CONGRESS.

Preliminary programmes have just been issued by the secretaries of Sections A, B and C of the International Electrical Congress to be held in September in St. Louis.

Section A.

Dr. E. L. Nichols is the chairman and Dr. H. T. Barnes the secretary of this section, which deals with "Theory." The following papers have been promised by foreigners:

A Paul Drude, "Metallic Conduction."
W. Jaeger, "Electrical Standards,"
Oliver Lodge, "Ions."
H. Nagaoka, "Magneto-Striction."
J. J. Thomson, subject to be announced.
J. S. Townsend, "The Theory of Ionization by Collision."
J. Violle, "Secondary Standards of Light."
C. T. R. Wilson, "Condensation Nuclei."
P. Zeemann, "Magneto-Optics."

The following papers have been promised by American scientists:

H. T. Barnes, "The Mechanical Equivalent of Heat as Measured by Electrical Means."
Carl Barus "Atmospheric Nuclei."
Louis A. Bauer, "The State of our Knowledge Regarding the Earth's Magnetism."
D. E. Brace, "Magneto-Optics."
H. S. Carhart and G. W. Patterson, Jr., "The Absolute Value of the Electromotive Force of the Clark and Weston Cells."
C. D. Child, "The Electric Arc."
K. E. Guthe, "Coherer Action."
E. P. Lewis, "Electrical Discharges in Gases."
L. T. More, "Electrostriction."
E. Fox Nichols, "The Unobtained Wave-Lengths between the Longest Thermal and the Shortest Electric Waves yet Measured."
E. L. Nichols, "Standards of Light."
Harold Pender, "Magnetic Effect of Moving Charges."
M. I. Pupin, "Electrical Theory."
Edward B. Rosa, "Alternating Current Measurements."
E. Rutherford, "Radioactive Change."
J. C. McLennen, "Radioactivity of the Atmosphere."
J. Trowbridge, "Electrical Discharge in Gases."
A. G. Webster, "Electrical Theory."

Section B.

This section deals with "General Applications," the chairman being Dr. C. P. Steinmetz, and the secretary, Dr. Samuel Sheldon. The following papers have been announced:

E. Arnold, "Direct-Current Commutation."
O. S. Bragstad, "Compensated Alternators."
R. E. Crompton, "Standardization of Dynamo-Electric Machinery and Apparatus."
Andre Blondel, "Calcul des Alternateurs."
J. Elster and O. Geitel, "Uber die Natürliche Radioactivität der Atmosphäre und des Erdbodens."
C. Feldmann, "The Distribution of Voltage and Current in Closed Conducting Networks."
A. Heyland, "Self-Regulating and Compounded Synchronous Machines."
W. M. Mordey, subject to be announced.
A. Nodon, "Rectifiers."
W. Preece, "Electricity in Ancient Egypt."
C. A. Adams, "Magnetic Leakage in Alternating-Current Machinery."
C. Day, "Electric Motors in Shop Service."
J. W. Esterline, "Carrying Capacity of Cables and Conductors."
H. W. Fisher, "Sparking Distances, Corresponding to Different Voltages."
H. J. Ryan, "The Design of Insulators."
D. B. Rushmore, "The Regulation of Alternators."
E. B. Rosa, "The Influence of Wave Shape upon Alternating-Current Meter Indications."
Clayton H. Sharp, "The Equipment of a Commercial Testing Laboratory."
H. B. Smith, "Very High Voltage Transformers."

Section C.

This is the electrochemical section of the Congress, the chairman being Dr. H. S. Carhart and the secretary Mr. Carl Hering. The following papers have been announced:

S. Arrhenius, "Methods of Determining the Degree of Dissociation."
W. Borchers, "Electrometallurgy of Nickel."
Sherard O. Cowper-Coles, "Electrolytic Methods for the Rapid Production of Copper Sheets and Tubes."
F. Dolezalek, subject to be announced.
J. Sigfried Edstrom, "Electrical Extraction of Nitrogen from the Air."
H. Goldschmidt, "Aluminothermics."
F. Haber, "Electrolytische Zerstörungen in der Erde."
P. C. L. Heroult, "Electrometallurgy of Iron and Steel."
J. Swinburne, "Chlorine Smelting."
W. D. Bancroft, "The Chemistry of Electroplating."
A. G. Betts and Edward Kern, "The Lead Voltameter."
H. S. Carhart and C. A. Hulett, "The Preparation of Materials for Standard Cells."
Thomas A. Edison, "Alkaline Batteries."
K. E. Guthe, "The Silver Voltameter."
Carl Hering, "The Units Employed in Electrochemistry."
J. T. Morrow, "Notes on Electrolytic Copper Refining."
J. W. Richards, "The Energy Absorbed in Electrolysis."
T. W. Richards, "The Relation of the Theory of Compressible Atoms to Electrochemistry."

The papers given above have already been promised. The following papers are also expected in the class of electrochemistry, but no definite promise has yet been received from the authors:

M. Berthelot, "Thermochemistry and Electrochemistry."
W. Hittorf, "Transport Numbers of Migration."
R. Lorenz, "Electrolysis of Fused Salts."
H. Moissan, "The Electric Furnace."
W. Ostwald, "Electrolytic Theory."
W. Nernst, "Theory of Solutions and the Dissociation Theory."
H. W. B. Roozeboom, "Phase Rule in Electrochemistry."
W. D. Bancroft, "The Chemistry of Electroplating."
D. H. Browne, "Electrolytic Production of Copper and Nickel."
B. Magnus, "Electrolytic Copper Refining."
T. L. Wilson, "Calcium Carbide."

Electrometallurgy of Iron and Steel.—A paper on this interesting and timely subject is to be presented by Messrs. F. A. J. FitzGerald and P. McN. Bennie before the "American Foundrymen's Association" in Philadelphia, on June 1.

The Calculation of Line Batteries.—In a paper recently presented by Mr. W. E. Winship before the American Institute of Electrical Engineers, the author developed formulas for the calculation of storage batteries to be used in tramway work. In this case the storage battery is discharged to supply the energy for the peaks of the load curve, while it is charged when the load is below the average; at average load it is a "floating" battery. The capacity should be reckoned approximately at the rate corresponding to the duration of all the net discharges and not at the rates at which the separate discharges occur. Comparative calculations should be made, considering, first, the cost of copper alone, and secondly, the cost of copper and batteries, for equivalent line voltages, also the cost and depreciation in the two cases together with the transmission losses. Credit is to be given to the battery for the decrease of cost of power, due to load equalization, and for its possibility of being used as a reserve in case of breakdown.

THE METALLURGY OF GOLD ON THE RAND GOLD-FIELDS.

BY CLEMENT DIXON AND M. TORRENTE.

So much has been written on this subject already that the paper now presented to ELECTROCHEMICAL INDUSTRY may savor somewhat of "ancient history" and repetition. At the same time the authors venture to say that there are many interested readers of this journal who will welcome a resumé of the metallurgical practices on these fields. We will first briefly refer to the work done here in the "early days" and follow the rapid advancement made up to the present time, when it will be seen what splendid progress has been made since the first mill—consisting of only five stamps—was erected on these fields in 1887, only seventeen years ago. From this date the flotation of companies and erection of mills proceeded with great energy.

Up to the year 1890 the gold recovery methods consisted simply of wet crushing, with 750-pound stamps and ordinary plate amalgamation followed by various concentration devices, such as buddles, blanket strakes, shaking tables, canvas tables, vanners, etc.

The oxidized banket ore, however, was not easily amenable to concentration and the percentage of concentrates caught was small. These concentrates were worked in various kinds of amalgamation pans or stored for future treatment. The total gold recovered in those days probably did not amount to more than 60 per cent of the original value of an ore, then going about an ounce to the ton or over.

The year 1890 marked a great advancement in the metallurgy of gold on the Rand, for both the chlorination process and MacArthur-Forrest cyanide process were introduced. The first chlorination plant was a Newbery-Vantin, but it was not very successful, and soon suspended operations. In the following year, 1891, the first Plattner chlorination works on these fields was erected on the Simmer and Jack mine for the treatment of concentrates, and plants of a similar type were afterwards erected and worked with much success on the Robinson Gold Mine and at the Rand Central Ore Reduction Co.'s works. The cyanide process, first introduced experimentally in May, 1890, however, was an indisputable success from the start, and at the end of the year the first plant—to work tailings by this process on what was then considered a large scale—was erected on the Robinson Gold Mine.

The vats were square wooden ones of about 40 tons capacity. The working cost on this plant in 1891—treating accumulated tailings—were fully 12/ per long ton and the consumption of cyanide was about 3.32 pounds per ton of tailings treated. The strength of solution used was about 0.5 per cent of KCy, and the actual extraction about 65 per cent of the original value of tailings averaging nearly 14 dwts. Caustic potash was the agent used to neutralize the acidity of the weathered tailings.

The introduction of the cyanide process revolutionized the whole aspect of the industry here, and enabled many low-grade propositions, that could otherwise never have been worked at all, to pay handsome dividends. The process has resulted in the mill now being regarded mainly in the light of a pulverizer, rather than a gold extractor, the percentage of gold caught by amalgamation (which is approximately 60 per cent from say 11 dwt. ore) not being the most important factor in the operations of to-day. The mechanical devices for the handling of tailings have been rapidly improved, and the old method of discharging the residue tailings by laborously shoveling them over the sides of the vats into trucks soon gave way to bottom and side discharge doors, and the capacity of the vats have been increased from 40 tons to 400 tons—the original square wooden vats being supplanted by huge circular steel ones.

To-day, instead of the sands and slimes being first run into dams and there filled into trucks and hauled back to the cyanide treatment vats, the method now in vogue is that of *"direct filling", i. e.*, the pulp as it comes from the mill runs into a sump from which it is at once elevated by a huge tailings wheel or pumps to the desired height above the cyanide vats to allow of all future operations being conducted by gravity. From the elevator the pulp is conveyed along a launder where it is automatically sampled and passes into hydraulic classifiers called Spitzlutten. These are boxes so constructed that the heavier sands and concentrates (amounting to about 10 per cent of the total pulp and assaying about 12 dwts. to the ton from an original ore averaging say 11 dwts. per ton) are separated from the remainder of the pulp, which are led off direct into vats for special treatment (either by cyanide or chlorination) while the lighter sands and slimes continue their course down the launder—where they are again automatically sampled—and then pass through a spitzkasten, which divides the pulp again into two products—"leachable sands" and "slimes."

A spitzkasten is an hydraulic classifier so constructed that by a definite pressure of water being introduced (in some cases, however, no extraneous water is required) at the bottom of the box, the slimes are borne upwards and over the edge of the box and flow through a further series of spitzkasten to the slimes vats, while the sands are drawn off through a pipe at the bottom, and are led away to the percolating vats. The sands product would represent approximately say 65 per cent of the elevated pulp and assay about 4 dwts.—the remaining 25 per cent of the plup being slimes assaying, say, 2½ dwts.

SANDS

The sands from the spitzkasten are conducted direct to collecting vats—super-imposed over the leaching or treatment vats, proper—and there deposited either by means of Butters & Meins rotary distributors, or by a large flexible hose which is manipulated by a Kaffir stationed in the vat who soon becomes experienced in obtaining the desirable even distribution of the sands throughout the vat. In the process of filling by either means the surplus water is continually escaping from the collecting vat, in the one case into a peripherial overflow launder, and in the other case through a side discharge door, the height of which is regulated by slats of wood and canvas aprons as the level of the sand rises in the vats.

When the collecting vat is filled with sand and the water drained off, a preliminary weak cyanide solution (say 0.1 per cent to 0.15 KCy and in the proportion of, say, 1 part of solution to 5 of ore) may be pumped on and allowed to percolate through the mass and through the filter mat at the bottom. The first part of this leached solution is sent to the weak wash sump to be used for final washings at end of treatment of a charge, while the remainder of this solution, as soon as it comes through with sufficient gold to warrant it, is sent to the gold extractor boxes. Having leached off this preliminary cyanide solution as dry as possible, about the same quantity of strong solution, .25 or .3 per cent KCy, is then leached through the charge, after which the bottom discharge doors of this super-imposed vat are opened and the whole charge—now moistened with cyanide solution—is shoveled through the air into the treatment vats underneath, and carefully leveled off. The charge is then allowed to remain in contact for some hours with a second strong solution and this is followed by a .2 per cent or .25 per cent solution, and again by two or three weak washes from .15 per cent down to say .05 per cent in strength, after which a small water wash, say to the amount of 1 to 10 completes the treatment.

The whole cycle of operations generally takes six days, and the total amount of solution used is from 1 ton to 1½ tons per ton of tailings.

The residue sands are then discharged through the bottom

or side discharge doors into trucks or on to belt conveyors and deposited on the waste dump.

Not only have the mechanical devices been brought to a high state of perfection, but the consumption of cyanide has been reduced from the 3 or 4 pounds per ton of a few years ago to, say, 1-3 of a pound per ton of tailings, and to-day the total working costs on a modern cyanide plant may be put down at, say, 2/6 to 3/— per ton including redemption.

Slimes

Following quickly on the introduction of the cyanide process for the treatement of tailings or leachable sands the question of slimes treatment presented itself and this was undoubtedly one of the biggest problems which metallurgists and engineers were confronted with on these fields. Of the total ore crushed about 75 per cent only is leachable sands, the remaining 25 per cent being slimes—a product so fine that it is impossible to leach solutions through a charge. Attempts were made to treat slimes—which had been accumulated in a dam,—by first drying in the sun and then passing through a screen mixed with coarse tailings, so as to enable cyanide solutions to be leached through the charge, but this was not a success, and in spite of many other ingenious devices, such as keeping the charge agitated with compressed air introduced into the false bottom of the vat under the filter cloth, and in various other ways, the successful treatment of slimes was not accomplished until the now well known decantation process was introduced in 1895.

This process is carried out in two ways. If accumulated slimes from a dam is being treated, the product,—having been hauled from the dam in trucks,—is passed through a grizzly provided with cutters, into a mixing vat fitted with mechanical stirrers, and here the slimes are mixed with water and thoroughly disintegrated. Lime is added (to neutralize the acidity formed by the weathering of the pyrites) and also to assist the subsequent settlements of the slimes, according to the requirements which are carefully estimated.

From the mixing vat the charges flow or are pumped into another vat and allowed to settle. The clear water is then decanted off the surface and replaced by a weak cyanide solution, say 0.01 per cent KCy, and the whole charge thoroughly agitated either by means of mechanical stirrers fitted in the vats, or by centrifugal pumps, as explained later.

When the slimes have been agitated with this cyanide solution for from 6 to 12 hours, the charge is transferred to another vat and allowed to settle, the gold-bearing solution is then decanted off and further agitation, with very weak cyanide solutions, follow as in the treatment of current slimes direct from the mill, described hereafter.

The difficulties in the economic treatment of accumulated slimes on these fields are very great. In the first place the product is very low grade, and as a rule it has been stored for some years in paddocks or dams on the veld and has become contaminated with all kinds of organic matter. Owing to its heavy plastic nature it is difficult to handle, and it requires a large amount of lime to neutralize the acid compounds formed by partial weathering of the pyrites. The dissolving out of the gold is also difficult, owing to the lower oxygen-absorbing compounds of iron present and the extra cyanide these compounds consume, and again the excess of lime salts and other complicated agencies in the gold-bearing solution render the precipitation of the gold most difficult and erratic. However, in spite of all the serious obstacles encountered, accumulated slimes are now being treated on these fields at a handsome profit.

The treatment of current slimes from the mill is a far more simple matter, and since 1895, when the decantation process was first introduced here by Mr. J. R. Williams, large profits have been made from what was up till that time considered a worthless product.

Briefly, the manipulation of current slimes is as follows: The product (after its separation from the leachable sands by means of spitzkasten already referred to) flows down a long launder, in which a certain amount of lime is added, to a further series of spitzkasten and the action of the added lime is such that the slimes settle in the spitzkasten and are drawn off at the bottom, while the superfluous clear water flows away at the top. This thickened slimes pulp is run into a slimes collecting vat, where it is allowed to settle, after which the clear supernatant water is decanted off, leaving the product in the vat of a consistency of, say, 1 part of dry slimes to 1 part of water. The charge is now transferred (to another vat into which a quantity of cyanide solution has already been pumped), through the discharge pipe in the center of the concave bottom of the vat, which is connected with a centrifugal sludge pump, and while the transfer is being made the pulp is thinned down and sluiced out into the suction of the pump by a cyanide solution, played onto the mass through a hose fitted with a small nozzle. The strength of this solution is such as to bring the whole of the liquor in the charge up to 0.01 KCy. Having emptied the collecting vat, the suction of the sludge pump is now connected up with the bottom discharge pipe of the tank to which the charge has just been transferred, and an ideal agitation and circulation of the charge is effected by thus drawing off the pulp from the bottom of the vat and delivering it on to the surface again through the centrifugal pump. This circulation of the charge under cyanide solution is continued for, say, 1 or 2 hours, according to the requirements of the particular ore under treatment. The charge is then settled and clear solution decanted off. A second transfer of the charge, and subsequent circulation, follows under precisely similar conditions, with the exception that the cyanide solution is very much weaker—as low as .001 per cent KCy or weaker. The function of this solution is simply that of a wash by dilution so as to reduce the final liquor left in the slimes, in both gold contents and cyanide, as much as possible. In some cases, according to the richness of the slimes, it may be advisable to again transfer the charge with a water wash to further reduce the value of the solution held by the slimes, as it will be seen that the whole process is simply one of recovery by means of dilution.

The treatment having been completed, the residue slimes, containing, say, 50 per cent moisture, are now sent to the residue slimes dam either by sluicing out direct with water or by passing through the same centrifugal sludge pump used throughout the operations, which can be connected up to deliver into the discharge pipe or launder going to the slimes dam.

In treating 2½ dwts. to 3 dwts. current slimes an extraction of, say, 75 per cent is obtained; the total amount of solution used would amount to 5 or 6 tons per ton of dry slimes.

The total cost of treatment, including redemption, may be put down at from 3/— to 3/6 per ton, so it will be seen that even from the poor 2 dwts. slimes treated on many of the mines a handsome profit is made.

As slimes often contain a considerable quantity of sulphides, organic matter, or other compounds that require oxidation, it has been found advisable to use additional air, and this is very effectually accomplished by means of compressed air introduced into the delivery pipe during the circulation of the slimes through the pumps as described.

When treating low-grade slimes, to avoid undue loss of cyanide and over-taxing the gold extractor boxes with a greater bulk of solution than necessary, the practice is to "concentrate the solution."

The first solution decanted off goes direct to the solution clarifying and storage vat and then through the extractor boxes, and from the sump at the foot of the extractor box it is pumped up and used to transfer the settled slimes from the first treatment vat to the second, and from the second treatment vat the clear solution is pumped direct to transfer the untreated but settled charge of slimes from the collecting tank to

the first treatment vat, which thus completes the cycle. In this way the solutions are built up in strength and gold-bearing contents for the more efficient and economical extraction of their gold contents.

Precipitation.

Now, with the introduction of the slimes process as described above, came the problem of the precipitation of gold from the necessarily very weak cyanide solutions employed—solutions too weak to yield up their gold by the ordinary zinc shavings method which is so effective with the stronger solutions obtained from the treatment of the leachable sands.

The successful precipitation of the gold from these very dilute cyanide solutions from the slimes plant was first accomplished by the Siemens & Halske electrolytic process which was introduced to these fields ten years ago, and after a very thorough and elaborate series of experiments the adaptability of the process to the work required of it was fully demonstrated and acknowledged to be a great improvement in many respects on the zinc process than is use.

The results obtained to-day by the Siemens & Halske boxes are about the same as when first introduced, but the great mechanical improvements which have been and are still being made have very considerably diminished both the initial and working costs of the plant. Ten years ago the working solutions used in the MacArthur-Forrest process varied from .25 per cent to .5 per cent KCy, and cyanide of potassium was then much dearer than it is to-day. The solutions used in the new electrical process were only .05 per cent to .15 per cent KCy, which thus made it possible to treat tailings and slimes of a very low grade value at a good profit. The claims of the two processes stimulated a healthy rivalry among metallurgists and engineers on both sides with the result that considerable improvements were made not only in both precipitation processes but also in the general arrangements of the entire plant.

At the May Consolidated Mine, where the electrolytic process was installed, a novel and most important change was made in the arrangement of the cyanide plant by building the collecting vats directly over the treatement vats, so that double treatment could be given to the ore at a minimum cost for transferring the charge from one vat to the other. This arrangement of super-imposed vats has since been adopted on all modern plants and has effected an enormous economy.

It will be interesting to follow the precipitation process from the start. In 1894, when the Siemens & Halske process was introduced, the position of its established rival was briefly as follows:

A 10 per cent royalty was charged for the use of the process.

Very strong solutions were used.

Precipitation of the gold from the solution was very good.

Consumption of zinc in the boxes was excessive and required replenishing constantly.

Clean up was complicated, tedious and wasteful of gold throughout.

An enormous quantity of rich slag was produced in smelting, no matter how well operations had been conducted.

Bullion bars were only 700 to 750 fine.

On the other hand the position of the Siemens & Halske process was:

A 2 per cent royalty charged.

Very weak cyanide solutions used.

Precipitation of gold from solutions not quite so good as in the zinc process.

Production of Prussian blue.

Once the boxes were in working order, very little attention was needed throughout the month.

Clean up extremely simple and little chance of any loss of gold.

Only a very small quantity of slags or skimmings of low value produced.

Bullion bars 950 fine.

It will be seen that the advantages at this time were in favor of the electrolytic process, and it was soon adopted by many companies who appreciated a process for which they only had to pay 2 per cent royalty, and which offered other advantages over the older process.

The new process would probably have been adopted by most of the mines had it not been for the fact that at this early stage of its development the MacArthur-Forrest patents in this country were upset, and thus the consideration of a 10 per cent royalty was no longer a factor in the case.

The keen rivalry which already existed between the advocates of both processes was now greatly accentuated and both sides worked hard for supremacy. Improvements to the zinc process rapidly followed, such as the treatment of gold slimes by sulphuric acid, the installation of filter presses to obtain the "clean up" in a fair shape for handling, smelting in reverberatory furnaces with clay-lined crucibles, etc.

The greatest drawback to the zinc process was the bad precipitation obtained from weak solutions, but this was also most successfully overcome by the introduction of the zinc lead couple which is accomplished by steeping the freshly cut zinc shavings in a weak solution (say 2 per cent of lead acetate). This couple, like several others which were tried, had been found fairly successful up to a certain point, but it was only when Mr. Betty hit upon the idea of adding a strong cyanide solution at the head of the precipitation boxes, that the activity of the zinc lead couple was fully exerted and gold sucessfully precipitated from the extremely weak solutions coming from the slimes plant.

The Siemens & Halske process was also greatly improved, but the now almost perfect precipitation obtained by the zinc-lead couple could not be obtained without incurring a big expenditure in the construction of the precipitation boxes and the advantages to be obtained would be very doubtful, owing to the increased amount of Prussian blue, which would be produced by the decomposition of the iron anodes added to which the extra amount of lead cathodes required would be out of proportion to the results obtained.

It will thus be seen that the position of the two processes to-day is briefly:

Zinc Process.

No royalty.

Weak solutions.

Good precipitation.

Consumption of zinc still large and boxes require continual attention, and under certain circumstances give a lot of trouble, which sometimes result in very serious losses.

Clean up greatly improved and simplified, but still very bulky and requires a lot of handling.

Acid treatment and subsequent refining by manganese dioxide produces very fine bullion, which is also the case when the clean up is treated with litharge in a reverberatory furnace.

Siemens & Halske.

This process figures much about the same as has been already explained, although considerable economies and improvements in plant have been made here also.

Among the greatest drawbacks of this process the production of Prussian blue figured largely, also the amount of labor entailed in having to bag all the iron anodes. These bags, after being a certain time in the boxes, became clogged with Prussian blue, lime salts, etc., and greatly increased the resistance of the boxes, thus rendering it necessary to change the bags. These discarded bags constituted a by-product, which went by the name of "sacking," which contained a very considerable amount of gold. Four years ago, it was discovered that after an iron plate had been in the boxes a certain time the surface became evenly coated with iron oxide, and that this coating was sufficient to prevent the short circuiting between the iron anode and lead cathode.

If the iron plates are allowed to become oxidized before placing them in the boxes, the same results are obtained.

Bright patches on the plates are troublesome as they produce short circuiting very easily; the current will rush through these parts as they offer less resistance to its passage. With a little care, however, it does not take long to overcome this trouble, and when once the plates are in good working order no further trouble is experience with them throughout their life.

The great advantages the use of bare anodes offer are evident. The resistance of the boxes is greatly reduced, the Prussian blue formed finds its way to the bottom of he box and the trouble and expense of repeatingly bagging is avoided and there is no by-product in the form of sacking.

The precipitation of the precious metals upon the cathode is also much cleaner and brigher.

The results obtained from the working of the electrolytic process during the last year have been most creditable and compare very favorably with the best results obtained by the zinc process.

In 1903, 239,385 tons of sands or tailings were treated by the Siemens & Halske plants which produced 54,794 ounces fine gold. The highest actual extraction was 87.16 per cent, and the lowest 76.91 per cent from, say, a 4-dwt. product.

"Slimes" treated during same period amounted to 129,137 tons and produced 17,370 ounces fine gold. The highest actual extraction was 87.72 per cent, and the lowest 59.2 per cent. This last figure, however, was exceptional as old accumulated slimes of the worst and most contaminated description were being treated on this plant and the extraction here has since been improved to over 70 per cent.

The working of the Siemens & Halske process has been so often described in detail that it may appear perhaps somewhat of an unnecessary repetition to further describe it, but, by way of complimenting his paper we may say the iron anode and the lead strip cathode have proved the most practical and effective. The average density of current used is about 0.04 ampere per square foot of anode.

The anodes are placed from 3½ inches to 5 inches apart, and the cathodes, consisting of three or four sheets of thin lead, cut into strips about 1 inch wide, and suspended from a two or three wire frame, are placed between the anodes, care being taken that they hang free of the iron anodes.

The size of the box, which has proved most efficient, is about 30 feet long, 4 feet 6 inches to 6 feet wide, and 5 feet deep. The compartments are about 2 feet 2 inches wide, and allow the easy placing of bunches of lead strips 4 feet long by 2 feet wide. The solution is circulated through one compartment into the next in an upward direction as in the ordinary zinc boxes.

Six boxes of this description will easily deal with all the solutions coming from a sands plant on the basis of 100 stamps crushing 5 tons a day.

The value of the gold contents carried in the solution entering the first two boxes, called the strong boxes, will in no material way influence the amount of gold carried off by the weakest solution after going through the last boxes, called weak boxes. That is to say, that no matter whether the solution entering the boxes carries 4, 10 or 12 dwts. of gold per ton, we find the solution leaving the box and going to weak storage does not increase proportionately to the original value of the solution, and it will always carry from .5 dwts. to a dwt. of gold per ton.

It is this apparently irreducible minimum that is the greatest drawback to the electrolytic process, and has retarded its progress to a great extent.

The following details obtained from one of the plants now working this process may be taken as a fair criterion of the work done all round.

Capacity of plant 8,000 tons of sands and coarse spitzlutten concentartes.

Precipitation Plant.

Six boxes, 30 feet long by 5 feet 6 inches wide by 5 feet deep, divided into six compartments, each 4 feet by 4 feet 8 inches.

Number of anodes (iron), thirteen, size 4 feet by 4 feet.

Number of cathodes (lead strips) twelve, size 4 feet by 2 feet (two frames, 2 feet by 4 feet, between each set of anodes).

Sheets of lead in each frame, three (2 feet by 4 feet size, weight 1 pound per sheet).

Amperes per box 125, volts 1.75.

The compartments of the boxes are coupled in parallel, and, each box or boxes, again in series with the next set, and so on. The total current used is 250 amperes, and e. m. f. 10.5 volts.

The flow of gold-bearing solution through the boxes is at the rate of 50 tons to 75 tons per 24 hours per box, and results are as follows:

Strong box—One, 50 tons per 24 hours. Solution entering boxes 6.4 dwts. gold per ton. Solution leaving box 1.63 dwts. gold per ton, = 74.5 per cent extraction.

Medium boxes—Three, 150 tons per 24 hours. Solution entering boxes, 5.36 dwts. gold per ton. Solution leaving boxes, 1.82 dwts. gold per ton, = 66 per cent extraction.

Weak boxes—Two, 150 tons per 24 hours. Solution entering boxes, 2.36 dwts. gold per ton. Solution leaving boxes, 1.32 dwts. gold per ton, = 44 per cent extraction.

An improvement on these results, from purely an extraction point of view, could, of course, be obtained by decreasing the rate of flow, which would mean the erection of more boxes as the quantity of solution used could not be decreased economically. The foregoing remarks, with reference to solutions from "sands" treatment, may be, generally speaking, applied to solutions from the slimes plant, due allowance being made for the difference in gold contents. Solutions from the slimes plant generally run from 1 dwt. to 2 dwts. per ton, and to precipitate them down to say 4 grains, leaving the boxes it would require about 8,000 square feet of active anode surface.

Ever since the introduction of the Siemens & Halske process now ten years ago, unceasing and strenuous efforts have been made to try and reduce the value of solutions leaving the boxes, as low, or lower, if possible, than the results now obtained by the zinc process which average, say, .09 dwts. per ton of solution. Eminent men, such as Professor von Oettingen, of the Leipzig University, have been consulted in the matter, but the solutions are still leaving the boxes with a dwt. of gold and the problem has yet to be solved.

Comparisons with the results obtained by this process in other countries are of little use, as the circumstances are so different and present an entirely different problem to that obtaining on these fields.

For instance, on a plant where the solutions entering the boxes carry from 15 dwts. to 30 dwts. of gold, 8 to 10 ounces of silver and 1 per cent to 2 per cent copper, it is considered highly satisfactory, if the solutions leaving the boxes do not exceed 3 dwts. of gold, 0.5 to 1 ounce silver and 0.5 per cent copper. Electrical processes are responsible for the only really satisfactory work done with such solutions as the above.

On some of the plants on the Rand the solutions entering the boxes only carry 3 dwts. gold, the silver and copper being negligible quantities.

A few years ago Andreoli obtained excellent results in London on an experimental electrolytic plant, and it was hoped that his process would prove as successful here as it did in London, but in practice it failed to improve matters with our working solutions. Briefly, the theory of Andreoli's process consists in using a peroxidized lead anode and an iron cathode. After the cathode is considered to be sufficiently coated with gold it is plunged into a bath of molten lead; the lead alloys with the gold, and after all the cathodes have been treated in this manner the lead bullion is cupelled.

After perusal of these details on the working of electrolytic processes, it will be seen that the field is still open to the

electrometallurgist. The ideal process sought is one that will precipitate gold from its solution down to, say, 4 grains per ton with a moderate size plant, will produce no by-products, and the bullion bar must be obtained in a simple manner and of a high standard of fineness.

That the Siemens & Halske process has been and is a very important factor in advancing the metallurgical practices on the Rand, both directly and indirectly, cannot be gainsaid. Electrochemistry is a science which is making rapid advancement and the day is probably not far distant when we shall see the imperfections of such processes as the Siemens & Halske overcome; even now the variations in costs and results between this and the zinc process are very slight, and, although at present the latter process shows a slightly better average in precipitation, the opportunities for losing gold throughout the various operations, before eventually producing a lead bullion for cupelling (which is obtained first hand in the electrolytic method) must go a long way towards counterbalancing its advantages under this head.

By-Products.

At the end of nearly, if not all, metallurgical operations, we find a product left which still contains a certain amount of the metal sought which cannot be recovered without special treatment. These materials are conveniently called by-products and the value of the original metal being exploited which they still contain, is the determining factor as to their ultimate disposal. These by-products can only be treated successfully in specially constructed plants, and as the individual mines do not produce by-products in sufficient quantities to warrant each in erecting special plants, the custom has been to accumulate the material for a time and then either ship it to the big metallurgical centers abroad or sell it to a local reduction works company.

The Rand Central Ore Reduction Co. was established here some twelve years ago, and erected very fine works for the special treatment of every kind of by-products produced on these fields and the majority of the gold mining companies availed themselves of these works for the disposal of all by-products.

In the early days here before the introduction of the cyanide process the by-products produced consisted principally of concentrates, black sands, sweepings, battery chips, and screenings, slags from the smelting of battery gold, old crucibles and ashes. Of course "tailings" and "slimes" also constituted a by-product in those days, but we have already described how the enormous accumulation of these materials, once regarded as nothing more than a nuisance, has since been turned into such a huge source of revenue through the cyanide process.

The working of this process is responsible for the production of most of the by-products which now have to be dealt with on these fields, such as slags, white slimes, Prussian blue, scrapings, sweepings, skimmings, dross, litharge, brick dust, test bottoms, old crucibles and liners, ashes, sump sediments, etc.

If the gold has been precipitated on zinc the subsequent smelting of the gold slimes results in the production of a considerable quantity of slags, containing more or less metallic gold distributed throughout the mass in the form of shotty prills, in which form, after grinding the slags, it can be recovered by cradling, but a large amount of gold remains which is so thoroughly assimilated by the slag itself as to render its extraction impossible by ordinary means.

As an example of the enormous amount of slag sometimes produced, in the days of smelting with ordinary plumbago crucibles in an ordinary furnace, we may mention that the proportion has been as high as 6 tons of slags for the recovery of about 2,000 ounces of gold.

On one of the mines every endeavor was made to obtain as high an extraction as possible from the slags by crushing them with water through a 700-mesh screen and amalgamating over specially prepared copper plates. A considerable amount of gold was recovered in this way after which the residue pulp was carefully collected in settling vats, placed below the copper plates, and this residue still contained from 10 to 12 ounces gold per ton. The residue slag pulp accumulated over a period of 7 years by this company was subsequently sold to the Rand Central Ore Reduction Company and realized about £12,000.

If the gold from the cyanide solutions has been precipitated electrolytically on lead sheets, the lead bullion obtained carries nearly all the gold, and this is readily obtained in a very pure state by cupellation. The by-products produced by this method are, skimmings, metallics from the smelting operations, and test bottoms from the cupellation. The metallics can be added to the lead when cupelling, but the remainder require special treatment at the smelting works. The "clean up" process from the zinc plant has fortunately been greatly improved. The first step was the introduction of reverberatory furnaces in which one or two dozen crucibles could be placed at the same time and their contents smelted at a uniform heat, this lessened the smelting operations considerably but the quantity of slag produced and crucibles used remained as before.

The next step forward was the treatment of the zinc clean up with sulphuric acid—special lead-lined clean up vats being used for this purpose.

These acid vats were covered over with a conical hood dipping in a peripheral launder filled with water which hermetically closed the whole apparatus—a flue or pipe fitted into the apex of the conical hood and conducted through the roof of the building carried off the gases produced in the vat.

After washing out all the soluble salts the gold slimes are pumped into a filter press and the resulting cakes dried, fluxed, and smelted.

By this means the amount of slag produced is greately diminished but it still carries a considerable amount of gold which can only be recovered by some special process.

The bullion produced by the old method of smelting with borax, soda, sand, etc., was of a low grade, from, say, 650 to 750 fine only, but by the use of manganese peroxide in the flux a very high grade bullion is obtained, the only drawback to this flux is that while it eliminates the base metals it also carries the silver into the slag.

The latest improvement in the smelting operations, known as the Tavaner process, consists of placing the acid treated zinc gold slimes in a reverberatory furnace with litharge and slag from the laboratory or any other convenient flux and a reducing agent.

This brings the precious metals into lead bullion, which is cupelled and yields a bullion of very high standard.

The slag produced by this method will be of very low grade value if the operations have been carefully conducted. The drawback to this process at present is the large amount of gold which remains locked up in the furnace, and the somewhat heavy cost for maintenance—nevertheless, it is a process working in the right direction, and has done a great deal towards enabling the individual mines to treat the various by-products on the spot, instead of selling to customs works.

Most of the mining companies here had hitherto sold their by-products to the Rand Central Ore Reduction Co.

For the last eight years this company has been treating by-products very successfully in pan and blast furnaces. According to the gold contents and nature of the by-product it was sent to either one or other of these furnaces.

Pan Furnace.

Slags from the zinc clean up, and any product assaying over 30 ounces gold per ton, were treated in the "pan" furnace.

The slag is fed into this furnace with a certain quantity of litharge and a reducing agent, such as coal or ground plumbago crucibles, the other by-products being added in

such quantities as would not interfere in obtaining a fluid slag. The litharge on being reduced combines with the precious metals contained in the charge and accumulates at the bottom of the furnace as lead bullion; the slag is drawn off as often as necessary and when the lead bullion has accumulated in sufficient quantity at the bottom it is also tapped off into moulds, and may be immediately cupelled and a high-grade bullion obtained. The disadvantages of the furnace were: the heavy wear and tear, and the large amount of gold which remained locked up in it, and which could not be recovered until the furnace was completely broken down; the gold left in the resulting slag generally amounted to from 2 to 4 ounces per ton, and the quantity of lead was also considerable, amounting to 8 to 10 per cent.

Blast Furnace.

By-products which for any reaspn could not be successfuly treated in the pan furnace were dealt with in a "blast furnace."

The principal fluxes used in this furnace were iron oxide and carbonate of lime; litharge and galena produced the lead which acted as carrier for the precious metals; and sulphurets served to produce a matte with whatever copper was present.

This blast furnace enabled by-products of any description to be smelted, but the high price paid here for the coke fuel and necessary fluxes rendered the work very expensive. For every ton of by-product, from 3 to 4 tons of fluxes and fuel had to be smelted, which considerably reduced the margin of profit.

The slags produced by this furnace seldom carried more than a few pennyweights of gold and silver or more than 1 per cent of lead, if of higher value they were repassed through the furnace.

The lead produced, which carries the precious metals and a small quantity of copper, was treated according to requirements. If the flux galena was abundant, the lead was deprived of the contained precious metals by the Parkes process.

Parkes Process.

This, briefly, consists of smelting the lead bullion bars obtained from the blast furnace in cast iron pots of about 20 tons capacity. The copper dross is skimmed off and zinc is then added to the mass of molten metal.

Zinc has the extraordinary property of seizing nearly all the gold and silver present, and bringing it to the surface in the form of a crust which is skimmed off. This scum—which consists of zinc, lead and precious metals—is sent to the pan furnace for the purpose of fluxing the zinc. When this has been done the lead bullion produced is ready to be cupelled at once. The zinc may also be distilled and the remaining lead cupelled to obtain the gold and silver. If galena is difficult to obtain, then the lead as it comes from the blast furnace is cupelled and the litharge so produced used again in the blast furnace as already described.

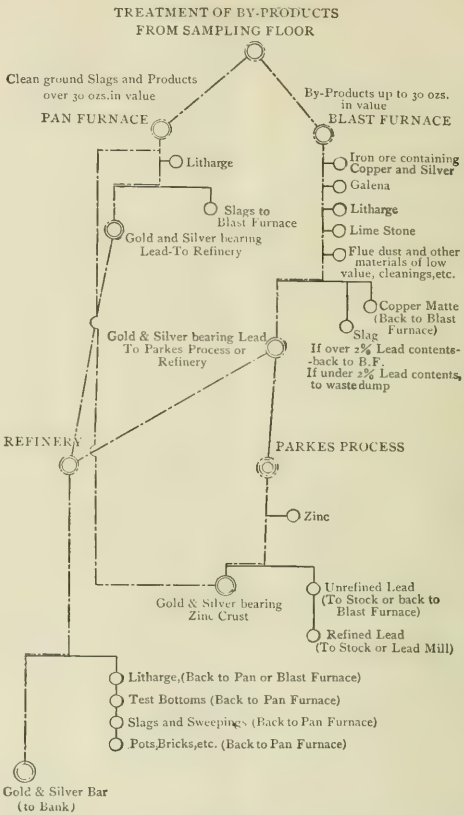
In cases where the use of galena results in a great excess of lead bullion, this is refined and converted into marketable lead after the precious metals have been withdrawn.

In connection with the blast furnace work a fair amount of flux dust is produced. This necessitates the regular cleaning of the flues and dust chambers where it collects. The collected dust is simply added to the charges and returned to the blast furnace.

The copper matte is also passed through the furnace with the object of concentrating it, and when its contents are considered sufficiently high, is shipped to Europe for further treatment.

All the refining which has been carried out at these works has merely consisted in the separation by cupellation of the gold and silver from the lead and other base metals—so far as can be done in this operation. The bullion bars of gold and silver have been sent to Europe for further treatment and disposal.

A graphic table is appended which will show at a glance the course of the by-products, fluxes, and secondary by-products, and will, we hope, render the foregoing pages relating to the Rand Central Ore Co.'s plant to be more easily understood.


TREATMENT OF BY-PRODUCTS
FROM SAMPLING FLOOR
Clean ground Slags and Products over 30 ozs. in value
PAN FURNACE
By-Products up to 30 ozs. in value
BLAST FURNACE
Litharge
Iron ore containing Copper and Silver
Galena
Litharge
Lime Stone
Flue dust and other materials of low value, cleanings, etc.
Slags to Blast Furnace
Gold and Silver bearing Lead-To Refinery
Copper Matte (Back to Blast Furnace)
Slag
Gold & Silver bearing Lead To Parkes Process or Refinery
If over 2% Lead contents--back to B.F.
If under 2% Lead contents, to waste dump
REFINERY
PARKES PROCESS
Zinc
Gold & Silver bearing Zinc Crust
Unrefined Lead (To Stock or back to Blast Furnace)
Refined Lead (To Stock or Lead Mill)
Litharge, (Back to Pan or Blast Furnace)
Test Bottoms (Back to Pan Furnace)
Slags and Sweepings (Back to Pan Furnace)
Pots, Bricks, etc. (Back to Pan Furnace)
Gold & Silver Bar (to Bank)

A paper recently read by one of the authors before the South African Association for the Advancement of Science on the "Evolution of the Treatment of By-Products on the Rand," has been of great assistance in the compilation of this paper.

In conclusion, although great advances have been made in the metallurgy of gold on the Rand, plenty of problems still await solution. Here money is generously, if not lavishly, spent if there seems any chance of effecting improvements, the friendly rivalry, coupled with the exceptional facilities which exist for the interchange of ideas and experiences, all help in the same direction, and this is one of the most pleasing and notable features of the scientific life on the Rand.

Johannesburg, South Africa, April 18, 1904.

American Institute of Electrical Engineers.—The annual meeting of this Institute was held in New York City at the Chemists' Club on May 17 and 18. It had the same experience as the American Electrochemical Society at its recent annual meeting in Washington, namely, that the attendance was comparatively small, probably on account of the coming International Electrical Congress in St. Louis. With the exception of a paper of Mr. W. E. Winship on the Calculation of "Floating" Batteries, no paper of special interest to electrochemical engineers was presented.

ELECTROLYTIC REFINING OF GOLD.

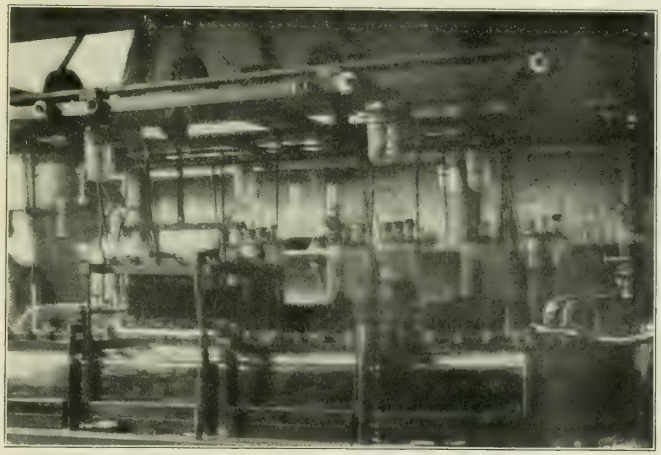
By Emil Wohlwill, Ph. D.

At the request of the editor of Electrochemical Industry, I herewith give some notes on the electrolytic method of gold refining, to supplement the article of Dr. Tuttle (Vol. 1, page 157, January, 1903). My electrolytic method of refining gold was introduced by Dr. D. K. Tuttle into the United States Mint of Philadelphia, and I am pleased that, after two years of use, he calls it "a great boon for the patrons of the United States Mint." This method was the result of experiments which were undertaken by me for the single purpose of investigating whether in parting platinum from gold the usual method can be replaced by an electric method. These experiments were made by me as director of the Deutsche Affinerie in Hamburg, and were begun in 1874. I established the following facts, which were unknown up to that date:

(1) In an electrolyte of chloride of gold which contains no other chloride, a pure gold anode, or an anode rich in gold, behaves like an anode of platinum or carbon. Chlorine is developed in gaseous form, while the gold is not dissolved.

(2) This development of chlorine gas can be prevented and gold is dissolved from the anode, if hydrochloric acid or certain other chlorides are added to the electrolyte of chloride of gold.

(3) There exists for a given solution a maximum of current density at which gold is dissolved from the anode without a development of chlorine gas. If the current density is increased beyond this maximum, chlorine gas is developed. However, by increasing the quantity of hydrochloric acid, or chlorides which act in the same way, and by increasing the temperature of the electrolyte, this maximum of the current density is increased.



GOLD REFINING ROOM OF THE DEUTSCHE AFFINERIE IN HAMBURG.

(4) In a solution of chloride of gold, even with the addition of hydrochloric acid or of such chlorides which have the same effect, and even with increased temperature, pure platinum is not dissolved from the anode, and causes, therefore, the development of chlorine gas. If, however, platinum is contained in an alloy with gold, and such an alloy is used as anode in an electrolyte of chloride of gold with an addition of hydrochloric acid, the platinum goes into the solution in the same manner as the gold, while at the cathode gold is precipitated, completely free from platinum, from the solution containing gold and platinum; the platinum remains in the solution.

These facts represent the principles upon which the method is based by which, since 1878, the Norddeutsche Affinerie in Hamburg produces chemically pure gold from impure gold, and especially from gold containing platinum. The facts given above also indicate a very simple way by which from gold containing platinum the smallest quantities of platinum can be completely won. Since platinum is dissolved from the gold anode, but is not precipitated from the solution, it is possible to collect the platinum from a great many impure gold anodes in the same volume of solution and to continue with this process until the concentration of the platinum in the solution is sufficiently high to permit direct precipitation by chloride of ammonium.

Electrolytic gold, produced by this new method from a material rich in platinum, was first exhibited at the Paris Electrical Exposition, in 1881, in form of the original cathodes as well as in form of bars which had been obtained by melting the former. At the request of M. Debray, at that time director of the Mint of Paris, the exhibited gold was subjected to an analysis. The test certificate of the Paris Mint, which I still have, records a purity of 1,000 in 1,000; M. Debray remarked that this is a purity which had not been obtained before.

The method as it was used at that time had an essential disadvantage besides its great advantages. It was the cleanest operation imaginable; any quantity of gold was dissolved in uncovered vessels, without producing any smell of chlorine. Even an evaporation of hydrochloric acid from the hot, but only slightly acidified solutions was scarcely noticeable. A higher price was paid for the precipitated gold on account of its purity. The operation, however, was very slow, much slower than the usual chemical method (solution by means of aqua regia and precipitation of the gold by protochloride of iron). With the chemical method the total contents of gold could be obtained in twenty-four hours from the largest quantities of gold containing platinum. On the other hand, the electrolytic process required generally three times twenty-four hours to obtain only about 80 per cent of the contents of gold as first product. This was evidently a very distinct disadvantage.

In order to reduce the electrolytic method to a really industrial process, it was therefore absolutely necessary to increase the speed of the operation. To a limited extent the speed could be increased by using anode plates of smaller thickness, but a really satisfactory reduction of the time of operation required a considerable increase of the current density, but this appeared to be impossible beyond a certain limit. When the current density was increased up to a certain limit, any further increase, either by increasing the current with constant anode surface or by diminishing the anode surface with constant current, resulted in the evolution of chlorine gas at the anode, and the quantity of gold dissolved from the anode was therefore smaller than that of the gold precipitated on the cathode.

The remedy was found in a consequent application of the principle indicated above under (3). On the basis of the facts stated there I had given for many years the following rule to my workingman: When you smell chlorine, measure at once the temperature; if the thermometer shows less than 67° C., heat the bath; if this is not sufficient to make the smell of chlorine disappear, add hydrochloric acid in small portions

such solu[illegible] At that time, as long as the increase of speed [illegible]eration was not absolutely necessary, I kept the average addition of hydrochloric acid as small as possible, and, as a result, I regarded a relatively low current density as normal. However, when I seriously asked myself the question whether the arbitrarily fixed limit represented really the normal condition (i. e., the limit attainable on account of the principle of the method) I soon discovered that this was by no means the case.

Experiments proved that by continually increasing the amount of hydrochloric acid in the electrolyte, continuous solution of the gold anode without any evolution of chlorine gas could be obtained at current densities which were six times greater than those which I formerly considered as normal; but less than one-half was sufficient for practical purposes, i. e., for an operation in which from any quantity of impure gold, 80 to 90 per cent of the total contents of gold are precipitated in the morning, if the plates had been placed into the baths the afternoon before. Only in this improved form the electrolytic method was able to completely replace the chemical method which up to that time had been used exclusively for the same purpose. That the substitution of the electrolytic for the chemical method was advantageous has been recognized first by the largest German parting plant, the Deutsche Gold und Silber-Scheideanstalt (vormals Roessler), in Frankfort-on-the-Main, many years after the introduction of the electrolytic method by the Norddeutsche Affinerie. In the Frankfurt plant the chemical method had been used for a long time for parting platinum from gold, it had been developed there to great perfectness, and had been employed on the largest scale. Since 1896, however, this chemical method was given up, and the electrolytic method was introduced instead, and the latter has since been used continually for refining of gold won in the plant.

Dr. Tuttle, in his article mentioned before, also calls attention to the very simple method of recovering all platinum contained in the gold as one of the advantages of the electrolytic method.

For the same main purpose, *i. e.*, for refining gold containing platinum, the Royal plant of Freiberg-Halsbrücke has installed in May, 1903, a smaller electrolytic plant, in which four months after erection more than 6 kg. of pure platinum had already been won.

It seems not superfluous to discuss somewhat more in detail the question how far a method for completely parting platinum and gold can be of practical importance.

Wherever exists an industry of noble metals the scrap from such industries represents an important object for the work of the parting plants. In this scrap a certain, not negligible, content of platinum will be present, for the reason that the manufacture of vessels which consist entirely or partly of platinum, or which are covered with platinum, takes place often at the same places as the manufacture of gold and silver articles. As a result, scrap will contain the three metals in various quantities. In view of the high price of platinum every well-conducted parting plant must endeavor to win the total content of platinum, besides gold and silver from the mixed scrap. This will be especially necessary if the parting plant has to pay for the platinum.

But this more incidental and irregular occurrence of platinum does not represent the richest of the sources from which platinum comes into the plants devoted to the parting of gold and silver. It is well known that in nature at many places gold and platinum occur together. In this way platinum contained in gold, together with its kindred metals, iridium, palladium, rhodium, etc., is supplied from the gold mines to the parting plant. Less attention appears to have been paid to the fact that even at places where platinum, iridium, etc., are not found separately, the gold and silver found in nature have been found to contain platinum.

More than fifty years ago Max Pettenkofer discovered the content of platinum in the noble metals, and stated that "all silver which is found in trade and which does not come directly from a parting plant, contains platinum, so that this metal, which has been considered as extraordinarily rare, can be obtained in larger and profitable quantities if the silver is subjected to a process in which the platinum remains in the residue, that is, on a large scale in the treatment with sulphuric acid and in amalgamation." Pettenkofer would add to-day, "and in the electrolytic method of parting silver containing gold."

As far as I know quantitative determinations of this contents of platinum in silver, or in gold, won from silver, have never been published, and in the literature I cannot even find notes which would confirm the statement of Pettenkofer that all silver which occurs in nature contains platinum. It should, therefore, be of interest to give here some data for which I am obliged to Mr. Ludwig Opificius, chief chemist of the Deutsche Gold-und-Silber-Scheideanstalt in Frankfurt.

At the time when a uniform system of money was introduced in Germany the largest part of the old German coins were melted and the melted metal was subjected to a parting operation. At that time Mr. Opificius tested the various kinds of silver coins and also several sorts of silver obtained from metallurgical plants, and determined the content of platinum in quantities of silver between 5 and 10 kg. The results obtained by him are given in Table I. (I add for the greater convenience of comparison figures for the content of gold which was determined simultaneously from smaller quantities, as far as they have been placed at my disposal by Mr. Opificius):

TABLE I.

		Gr. gold.	Gr. platinum.	Gr. platinum per 1 Gr. Gold.
10 kilogram	French Laubthaler	...	0.016	.....
5 "	French Laubthaler	...	0.009	.....
5 "	Spanish Saulenthaler	2.8	0.011	0.0039
10 "	Coins, each 1/6 thaler	4.5	0.025	0.0055
10 "	Coins, each 1/6 thaler	4.5	0.0225	0.0050
10 "	Coins, each 1/3 thaler	2 to 3	0.0275	0.0110
10 "	Thaler	...	0.0145	.....
10 "	Thaler	...	0.0245	.....
10 "	Prussian Thaler (from 1820 to 22)	6.2	0.016	0.0026
10 "	Conventionsthaler	6.5	0.0165	0.0025
10 "	Conventionsthaler	6.5	0.0180	0.0028
10 "	Kronthaler	7.6	0.0250	0.0033
10 "	Kronthaler	7.6	0.0245	0.0032
10 "	Coins, each 20 kr. (Austria)	1.5	0.0135	0.0090
10 "	Coins, each 20 kr. (Austria)	4.8	0.0229	0.0046
10 "	Iambos	2.2 to 4.7	0.0300	0.0136—0.0078
10 "	Iambos	...	0.0365	.....
10 "	Emser Silber	4 to 6	0.029	0.0058
10 "	Emser Silber	...	0.029	.....
10 "	Eschweiler Silber	5 to 10	0.0482	0.0096—0.0048
10 "	Eschweiler Silber	...	0.0477	.....

The average of sixteen determinations in Table I. shows, therefore, that gold parted from silver by means of sulphuric acid or electrolysis contains 6 milligrams of platinum per one gram of gold. This corresponds to a value of about $1.00 for each 10 ounces of gold.

Mr. Opificius has not published these figures, because in dissolving the silver in his experiments, concentrated sulphuric acid was used. According to investigations made at a later date this acid can never be considered as free from platinum if it was concentrated in platinum vessels. It is, therefore, possible that a part of the platinum which was found came from the acids; its amount cannot be estimated; the same suspicion might also be raised against the observations of Pettenkofer. No investigation has as yet been made whether in parting silver by means of sulphuric acid containing platinum, platinum is really precipitated.

I do not think it is probable that the quantity of platinum which in this way is added to the original content of platinum in the noble metals is an appreciable amount. In the Norddeutsche Affinerie, in Hamburg, gold and silver were parted exclusively by means of sulphuric acid up to 1894; in the next years this method was replaced by the electrolytic process with the use of a nitrate solution, first only to a small degree, later on nearly completely. The material of the parting operation was essentially the same before and after 1894; all

gold which was obtained was afterwards treated to win the platinum from it. If a considerable amount of the platinum obtained in this way had come from the use of sulphuric acid the total quantity of platinum recovered should have decreased in considerable degree as a consequence of the introduction of the electrolytic process. From the record books of the Norddeutsche Affinerie, however, such an influence has not been found at all. The figures of Mr. Opificius may, therefore, be considered as not completely certain for the circumstances mentioned, but there is no reason why they should not be considered as approximate figures for the real content of platinum in the tested sorts of silver.

These figures relate, as can be easily seen, to silver with a relatively small content of gold, which was not parted at that time since the small quantity of gold would not have paid for the cost of the operation of parting by the method in use at that time. The investigations of Pettenkofer also appear to refer mainly to silver poor in gold. From the experience of the German parting plants, however, there is no doubt that the content of platinum is not limited to such sorts of silver poor in gold. It seems very probable that American silver is no exception from this general rule. Up to the present I have tested only a few products of American silver parting plants, but have found in them platinum without any exception, and in some a relatively high content of platinum.

Considering the large quantities of noble metals in various mixtures which are produced every year in the United States, we may conclude from the facts mentioned that very considerable quantities of platinum are supplied to the works which part gold containing silver or silver containing gold. In view of the present market price of platinum we must assume that the income of the producer and refiner would be increased by a considerable amount if the platinum would be extracted from the gold in which it is contained. One more reason why this extraction should be carried out is that while for his main purpose the refiner may not need to undertake the recovery of platinum, yet he cannot avoid to separate this substance if it is present in his gold. Even before it was known that platinum exists in pure gold, refiners used to remove the unknown impurity by repeatedly melting with potassium nitrate, and the same method is to-day used by those who want to get as pure gold as possible without parting the platinum from it by a special process.

The presence of platinum in any considerable quantity results in a certain quantity of silver being retained in the gold in such a way that it cannot be removed by the ordinary methods of parting. Moreover, where there is platinum there is very often also a certain addition of iridium, which, even in very small quantities, renders the gold brittle. These disadvantages can, indeed, be overcome by melting with potassium nitrate. One obtains by this method nearly pure gold, since platinum and iridium with a small quantity of gold pass into the slag, from which the platinum may then be obtained in a somewhat roundabout way, which has already been described by Pettenkofer. It may be doubted that this method is used to any extent in the United States, either by the producers of gold or by the parting plants to which the slag is sold. It is at least certain that scrap of various kind is exported every year abroad containing, besides gold, very considerable quantities of platinum.

It seems superfluous to remark that in comparison with a process by which, as described, an obnoxious although valuable impurity is simply removed, another process is preferable by which the valuable impurity is not merely removed, but recovered in a simple way. If we apply this general remark to the refining of gold it means that the rational solution of the parting problem must consist in a process by which the gold is obtained in an entirely pure condition, while the total platinum which was present in it is also recovered.

For this purpose, since Pettenkofer's discovery, the repeatedly mentioned chemical method has been in use which had also been suggested by Pettenkofer. The impure gold is dissolved in aqua regia, and from the dilute solution the gold is precipitated by protochloride of iron, free from platinum, etc. The solution from which the gold has thus been removed, is treated with metallic iron, and all platinum is thereby precipitated, first mixed with most of the other impurities of the gold. The advantages of the electric process, in comparison with this method, are of a manifold nature.

Whoever has been accustomed to dissolve larger quantities of gold every day in a mixture of hydrochloric and nitric acid, making use of more or less good ventilation, will scarcely consider it a disadvantage that in this process it is impossible to avoid the enormous development of gases and vapors of horrible smell and detrimental to health. Nevertheless, I have not yet found anybody who was accustomed to this disadvantage and who was not pleasantly surprised when entering the working room of a gold electrolytic refining plant and found that here a continuous solution of gold took place under the action of the current in open baths without the slightest development of smelling gas. It may be claimed that in our days the possibility of replacing an industrial process by another one which is better in hygienic respects, and has no other disadvantages, represents a serious consideration in favor of the latter. Of greater importance, however, will be the proof that the new method is also superior in diminishing the cost. I believe that the electric method of gold refining fulfills this condition.

The consumption of acid is more than fifty times greater with the chemical method, and against this main item of cost there is, on the side of the electrolytic process, only the cost of electric energy, of which a very small amount (about 300 watt-hours per kg. gold) is sufficient. For wages an amount is to be charged which is certainly not higher than for the work with aqua regia, especially since in accordance with the nature of the process, the work is not interrupted during the night, but is so arranged that that part of the electrolytic action which needs no attendance whatever, goes on during the night hours; for the manual work which is to be done during the day hours not more than one workingman is required for the treatment of 50 kg. (of rather pure gold). An estimate of the wages will, therefore, give a result in favor of the electric process even if a proper interest is charged for the continual stock of gold which is required for the electrolytic process, and if an extra charge is made for melting the scrap of the anodes and of fine gold serving for the cathodes.

Of the other advantages of the electrolytic process I briefly mention the greater chemical purity of the obtained gold, the essentially greater simplicity of recovering the platinum, and the complete separation of platinum from iridium and other platinum metals.

Platinum can be obtained directly by the chemical process only if the content of platinum in the gold is very high; it is the more complicated the smaller the quantity of the platinum in the gold. In the electrolytic process very small or very large quantities of platinum in the gold anodes pass into the electrolyte with equal facility, and the production of platinum from the electrolyte is always direct.

By the treatment with aqua regia a part of the iridium is dissolved together with platinum, iridium being nearly always present where there is platinum. From such a solution containing iridium, the platinum is then precipitated mixed with iridium if one does not use a specially complicated method for parting the two metals. On the other hand, platinum which has accumulated in the electrolyte, and which is obtained from it by precipitation, is absolutely free from iridium, because the latter is not dissolved from the anode by the action of the current. Iridium and osmium-iridium, which are present in gold, accumulate therefore completely and free from platinum in the anode sludge and may easily be obtained from the latter.

After all that has been said, the electrolytic process of refining gold appears to be especially suitable for overcoming a deficiency in the chemical and electrochemical industries of the United States; this deficiency is the non-winning of platinum present in gold. The production of platinum, as recorded by American statistics, certainly does not differ very much from a complete lack of production of platinum.

According to the statistics in Rothwell's *Mineral Industry*, the total production of platinum in the United States during eight years was as follows:

1895	150	ounces.
1896	162	"
1897	200	"
1898	300	"
1899	0	"
1900	173	"
1901	1408	"
1902	94	"

If we neglect the exceptionally high output of 1901, the average production was 154 ounces per year. The output of the year 1902 is the lowest on record since the statistical data on the production of platinum in the United States were undertaken. That the above quantities of platinum are parted from gold is said on page 569 of volume 7 of *Mineral Industry*. But the relatively high quantities of iridium which are mentioned side by side with platinum, justify the supposition that the produced platinum was not the result of a real refining process of gold, but came from the treatment of a mixture of gold with platinum ore. On the other hand, there cannot be any doubt that such refining processes are carried out in the United States on a very large scale, and cannot be carried out, or, at least, will not be complete without the separation of platinum. It would be interesting to find out what has become even only of those quantities of platinum which were won together with gold in the anode sludge, since the introduction of the electrolytic treatment of silver, and which were parted from the gold during the treatment of the sludge.

What has happened to platinum during this time has also happened to the corresponding quantity of iridium, since in gold containing platinum, iridium is nearly always present.

Much greater is probably the amount of palladium which was obtained at the silver anode of the Moebius refineries, but was not won from the sludge. It is known that in the Sudbury district in Ontario copper ores containing nickel are won and treated which also contain platinum and palladium in no small quantities, and that in these ores the content of palladium is very near to that of platinum. It was probably raw copper produced from these ores which was treated more than twenty years ago in large quantities in Hamburg under my direction. By electrolytic treatment of the copper, an anode sludge was obtained which was surprisingly rich in palladium. Together with the platinum which was also present, it was collected by a metallurgical process in silver containing gold; it was separated from the silver together with gold; as part of the gold anodes it passed into solution during electrolysis and from the solution it was completely recovered in pure form.

There is good reason to believe that the Sudbury ores are not the only ones in America in which the quantity of palladium present together with platinum is considerable. I do not know the price of palladium in the United States, but I know that one of the most prominent platinum factories of Germany pays at present 2,000 marks ($476) for one kilogram of palladium. It is therefore possible that if palladium is present, the value of the material thrown away with the ordinary parting method is very considerable. This amount could be easily recovered by the use of the electrolytic method.

In a second article the electrolytic separation of gold from gold alloys will be dealt with.

Hamburg, Germany, May 5, 1904.

ANALYSIS OF REFINED COPPER.

In our March issue, pages 87 to 95, we published a paper on "a laboratory study of the stages in the refining of copper," presented by Messrs. H. O. Hofman, C. F. Green and R. B. Yerxa to the American Institute of Mining Engineers. With reference to this paper, Mr. Lawrence Addicks has communicated to the secretary of the Institute some interesting critical notes which have just been published. Mr. Addicks starts with the statement that the excellent series of photomicrographs given in the paper referred to (pages 89 and 93 of our March issue) shows clearly the relation between micro-structure and cuprous oxide in refined copper. The authors suggest that this method of examination might be substituted for the "button" method now used to control the refining of copper and that, with the aid of a planimeter, it might displace the present tedious methods of analysis for oxygen-content.

Mr. Addicks points out, however, that the photographs of the button-fractures (page 91 of our March issue) show that the fracture at various stages is quite as characteristic as the micro-structure—which is to be expected, as one depends upon the other—and to a practiced eye enables the process to be followed as closely as would be possible with micro-samples, except toward the very end of the poling operation. But at that stage we have the surface or set of full-size castings to guide us. He emphasizes the fact that it is not a certain percentage of cuprous oxide in the casting which is sought, but such a quantity as will give a mechanically perfect product. This quantity varies through a very small range depending upon the size and shape of the casting. The pitch is easily brought close to the proper point with the guidance of the buttons, and any final adjustment made by judging the surface of a larger casting. The pitch is easily brought close to the proper point with the guidance of the buttons, and any final adjustment made by judging the surface of a larger casting. Personally, Mr. Addicks says he cannot see that the use of micro-samples would give any better guidance, and with anode copper in which are varying quantities of numerous impurities, the micro-structure would not be so readily interpreted.

As to the tediousness of the analysis for oxygen, Mr. Addicks says the simplest way to avoid this is to omit it altogether. The buyer of refined copper wants two things—satisfactory electrical conductivity and a mechanically perfect casting. The conductivity is specified because so much copper finds its way into electrical uses. The purchaser relies on the conductivity requirement to give him a copper so pure that it has satisfactory physical properties, and any analysis of refined copper is rarely necessary. Small variations in pitch are noticeable in the set of the castings long before the conductivity is appreciably affected. In regard to the development of the structure of samples of copper, he has had good results by treating the specimens for about 30 seconds in boiling aqua regia diluted with an equal volume of water. Under this condition comparatively little preliminary polishing is required.

American Institute of Electrical Engineers.—The report of the Board of Directors at the recent annual meeting shows that the Institute is in a flourishing condition. With the present month the membership has reached the remarkable figure of 3,000, while it promises to run up very soon to 3,300. The rate of increase in membership is now between 800 and 900 new members per year, which is a very high figure. The building fund for the Institute's share in the Union Engineering Building project has already passed the mark of $60,000, due to the splendid response of members to the request for contributions. The new president is Mr. John W. Lieb, who has been connected with Mr. Edison in his first electrical undertakings; he is at present third vice-president and associate general manager of the New York Edison Co. Like the American Electrochemical Society, the Institute will take a prominent part in the International Electrical Congress in St. Louis in September.

STUDIES ON THE SIEMENS PROCESS FOR WINNING COPPER.

BY M. DEK. THOMPSON, JR.

The following is an abstract of an investigation that was performed in the electrochemical laboratory of the Polytechnikum at Zürich under the direction of Prof. R. Lorenz, during the summer term of 1902 and the winter term of 1902-03. The author wishes to express here his appreciation of the assistance and encouragement given by Prof. Lorenz while this work was carried on.

The two most noteworthy attempts to win copper directly from the ores are the Hoepfner process and the Siemens process. Published investigations on the former of these have appeared,[1] but up to the present time no published account of tests relating to the Siemens process is to be found.

The Siemens process may be briefly described as follows. The ore is ground so as to pass through a fine sieve and then roasted. It is stated by the Siemens firm that roasting is not necessary with all ores. This is then treated at a temperature of 90°, with a solution of ferric sulphate, to which a little sulphuric acid is added. On dissolving the copper, the iron is reduced to ferrous sulphate. This solution of copper sulphate and ferrous sulphate is then led into the cathode compartment of a cell whose anode is separated from its cathode by a piece of linen. Here a part of the copper is deposited on the cathode, and the solution circulates through the diaphragm to the anode. This consists of carbon rods. At the anode the ferrous sulphate is oxidized to ferric sulphate which is used again to dissolve up fresh portions of copper.

THE DISSOLVING ACTION OF FERRIC SULPHATE.

The first part of this investigation consisted in experiments to determine how well ferric sulphate dissolves various copper compounds which were likely to occur in a roasted ore. The experiments were carried out in 100 cc. bottles, which were rotated in a thermostat at 80° C. The thermostat was constant to about a degree.

The ferric sulphate used in these experiments was obtained from Kahlbaum. Complications were introduced by the fact that the sulphate contained free acid. For instance, a solution was made up by dissolving the white powder in water, without adding acid. Analysis showed, however, that instead of 14.460 grams SO_4, corresponding to 5.618 grams iron in 100 cc. of the solution, there were really 20.120 grams SO_4, which corresponds to 5.78 grams free sulphuric acid.

EXPERIMENTS WITH CUPRIC OXIDE.

The first experiments made were with copper oxide. This was obtained from Bender & Hobein. The percentage amount of copper contained was 78.1, as compared with the theoretical 79.9 per cent.

[1] Zeitschrift f. Elektrochemie, 1895, 25; Zeitschrift f. anorg. Chem., 30, 18.

The only possible way ferric sulphate can dissolve copper oxide is by a more or less complete exchange of SO_4 for the oxygen combined with the copper. If in the exchange ferric sulphate loses all its SO_4, the equation would be the following:

(1) $3CuO + Fe_2(SO_4)_3 = 3CuSO_4 + Fe_2O_3$, or

$3CuO + Fe_2(SO_4)_3 + 3H_2O = 3CuSO_4 + 3Fe(OH)_3$

On the other hand, partial exchange may take place, represented by the following equations:

(2) $2CuO + Fe_2(SO_4)_3 = 2CuSO_4 + Fe_2O_2SO_4$

(3) $CuO + Fe_2(SO_4)_3 = CuSO_4 + Fe_2O(SO_4)_2$

The same equations are obtained by supposing that ferric sulphate reacts with ferric oxide formed in equation (1):

$6CuO + 2Fe_2(SO_4)_3 = 6CuSO_4 + Fe_2O_3$

$2Fe_2O_3 + Fe_2(SO_4)_3 = 3Fe_2O_2SO_4$, giving by addition:

$2CuO + Fe_2(SO_4)_3 = 2CuSO_4 + Fe_2O_2SO_4$

and $3CuO + Fe_2(SO_4)_3 = 3CuSO_4 + Fe_2O_3$

$Fe_2O_3 + 2Fe_2(SO_4)_3 = 3Fe_2O(SO_4)_2$, giving by addition:

$CuO + Fe_2(SO_4)_3 = CuSO_4 + Fe_2O(SO_4)_2$

If basic salts are formed this way, the total amount of SO_4 would never be available for dissolving the copper.

The first experiments given in table 1 were made with 50 cc. of a solution of ferric sulphate containing enough free acid to dissolve 1.862 grams copper, and 2.809 grams iron (except No. 1).

TABLE 1.—TEMPERATURE 80°.

No.	Grm Fe in the Solution.	Grm Cu Dissolved.	Grm Fe Reduced	Duration of Experiment.	Molecular Ratio $CuO : Fe_2(SO_4)_3$.	Grm Cu in the CuO Used.	Residue
1	2.833	1.509	0.032	15 min.	1:1	1.601	....
2	2.809	3.180	0.054	3 hrs.	2:1	3.218	small
3	2.809	..	....	4½ hrs.	4:1	6.436	..
4	2.809	...	....	4½ hrs.	8:1	12.88	.

In the first experiment all the copper was presumably dissolved by the acid, since no iron was precipitated. In No. 2 the amount of CuO shaken with the ferric sulphate was increased. After rotating in the thermostate for three hours, a very small quantity of sediment remains undissolved, and the solution was a deep brown. As is seen from the table the amount of copper dissolved was greater than the amount of acid could account for, and still no appreciable amount of iron was precipitated. On acidifying the solution it turned blue. This was the only case where ferric sulphate dissolved copper without itself being precipitated.

In experiment No. 3, where still more CuO was shaken with the same amount of solution, a voluminous brown precipitate containing crystals of copper sulphate was found in the bottle after allowing it to cool. In experiment 4 it was so thick that it could not be poured out of the bottle. The next experiments were therefore made with a solution of ferric sulphate just one-tenth as strong. Table 2 gives the results.

TABLE 2.—TEMPERATURE 80°.

No.	Ratio of $CuO + Fe_2(SO_4)_3$	Gram CuO Used.	Grm Cu Contained by CuO	Grm Fe in 50cc of Solution.	Duration of Exp.	Grm Cu Dissolved.	Residue.	Gram Fe in 50 cc of Solution	Total Amt Fe in 50 cc.
1	1:1	0.2037	0.1592	0.2809	4 hrs.	0.1592	.....	.....	0.2809
2	3:1	0.6111	0.4776	0.2809	4 "	0.4692	red	0.0073	0.0688
3	5:1	1.018	0.7960	0.2809	4 "	0.6435	reddish brown	.....	.....
4	10:1	2.061	1.609	0.2833	5 hrs. 40 min.	0.3579	brown	.....	0.0058
5	10:1	2.061	1.609	0 2833	2 hrs.	0.6149	brown	.....	.. .
6	10:1	2.037	1.592	0.2809	1 "	0.6399	reddish brown	.....	.. .
7	10:1	2.037	1.592	0.2809	2¾ hrs.	0.5146	yellowish brown	.....	.....
8	10:1	2.037	1.592	0 2809	5 hrs. 35 min.	0.3643	brown	....	....
9	2:1	0.4074	0.3180	0.2809	" "	0.3136	red	0.108	0.1744
10	....	0.2754	0.2205	0.2809	50 min.	0.2205	.....	.....	0.2809
11	....	0.8736	0.6995	0.2809	50 "	0.5099	yellowish brown	.....	.....
12	....	0.8736	0.6995	0.2809	2 "	0.5727	" "	0.108	0.100
13	....	0.8736	0.6995	0.2809	4 hrs.	0.5788	" "	0.0974	0.0933
14	....	0.9590	0.7663	0.2809	5 "	0.7056	" "	.....	.....

Experiment 1. Here there was less than 0.1862 gram copper present. This was dissolved by the acid and the iron remained unchanged.

Experiment 2. Here 0.4692 gram copper was dissolved and 0.2121 gram iron precipitated, but only 0.2830 gram copper was brought into solution by the ferric sulphate. According to equation (1) this amount of iron should have dissolved 0.3613 gram copper, according to equation (2) 0.2404 gram, and according to equation (3) 0.1202 gram. The amount actually dissolved, assuming that 0.1862 gram was dissolved by the free acid, therefore lies between (1) and (2). The small amount of iron in the ferrous state formed undoubtedly comes from impurities in the copper oxide.

In experiment (3), by a similar computation, it was found that the amount of copper dissolved lies between what is required by equations (1) and (2).

Experiment 4. Here both the amount of copper present and the duration of the experiment was increased. In spite of this the amount of copper dissolved was less than in experiment (3). It seemed probable that this was caused by the copper oxide, which still remained unchanged, acting on the copper sulphate to form some basic salt. This supposition was tested in experiments (5) to (8) in which the amount of copper oxide was kept constant, but the duration of the experiment varied. The table shows that with increasing time the amount of copper in solution diminished. All the iron was completely precipitated during the first hour, as shown in the table. The above explanation was therefore verified. The precipitation of copper from a solution of the sulphate by means of copper-oxide, was further tested by shaking 50 cc. of a solution containing 0.6 gram copper, with as much copper oxide as 0.6 gram Cu is contained in. After seven hours' rotation the solution contained 0.4172 gram copper, and a white precipitate had formed.

It was of interest to analyze one of the precipitates that formed in the experiments. Their appearance did not vary much from one experiment to the next. That obtained in experiment 4 gave the following result: 43.98 per cent Cu, 11.13 per cent Fe, 20.67 per cent SO_4.

Analysis in experiments 7 and 8 showed that the amount of SO_4 corresponded with the amount of copper, and therefore no free acid was present. Experiment 10 confirms the assumption that if exactly as much copper is present as the free acid will dissolve, the ferric sulphate remains unchanged.

Experiments 11 to 15 were made to see if it were possible to effect a complete exchange of SO_4 between copper and iron, but it did not prove possible.

In the actual process of extracting the ore ferrous sulphate will always be formed. Before leaving the copper oxide it was desirable therefore to see if this reacted in any way on ferrous sulphate. The following reaction might take place:

$$CuO + FeSO_4 = FeO + CuSO_4.$$

A neutral solution of ferrous sulphate which contained 0.2809 gram iron in 50 cc. was shaken with an equivalent amount of copper oxide. 0.1942 gram of copper was dissolved and 0.1906 gram of iron precipitated. The amount of copper is about 10 per cent too little for the above equation. It is probable that this is due to the action of the copper oxide on copper sulphate, just as in the previous cases.

A necessary conclusion from these experiments is that if a large excess of copper oxide is present, all iron and copper will be precipitated. A ferrous sulphate solution was shaken four hours with fifty times the equivalent amount of copper oxide. At the end of this time it was found that all copper and iron had been thrown out.

1. The investigation of the action of ferric sulphate on cupric oxide leads to the conclusion that the reaction between the two is probably represented by the equation:

$$3CuO + Fe_2(SO_4)_3 = 3CuSO_4 + Fe_2O_3,$$

when the two are present in equivalent quantities. When this is not the case, basic salts are formed to a considerable extent.

2. Copper sulphate is precipitated by copper oxide. When the amount of oxide is equivalent to the amount of copper in the solution, the precipitation is only partial; in the presence of a large excess of copper oxide, it is complete.

3. A metathesis takes place between copper oxide and ferrous sulphate, analogous to that with ferric sulphate. Ferrous oxide and copper sulphate are the resulting products.

4. It was shown that under certain conditions all iron and copper salts could be thrown out of solution.

Experiments with Cuprous Oxide.

The next experiments were on cuprous oxide. The sample used was obtained from Bender & Hobein. The percentage amount of copper contained was 83.2 per cent, instead of 88.8 per cent. There was a trace of manganese, which was precipitated on the anode during electrolysis.

The first experiment is tabulated below:

Table 3.

Wt. Cu_2O	Wt. Cu in Cu_2O	Ratio of $Cu_2O + Fe_2(SO_4)_3$	Gram $Fe^{...}$ in Solution.	Duration of Exp.	Temp.	Gram Cu Dissolved.	Grm. Fe Reduced.
1.934	1.609	1:2	2.833	17 min.	80°	all	1.34

The amount of iron that should have been reduced by 1.609 grams copper, assuming the equation,

$$Cu_2O + Fe_2(SO_4)_3 + H_2SO_4 = 2CuSO_4 + 2FeSO_4 + H_2O,$$

is 1.41 grams, which is more than that found. This difference of 5 per cent is easily explained by the probability of the presence of some cupric oxide which would be dissolved by the acid alone. In an experiment using twice as much cuprous oxide the copper sulphate partly crystallized out on cooling, so that the following experiments were made with a solution of ferric sulphate ten times as dilute. The results are given in table 4.

Table 4.

No.	Ratio of $Cu_2O + Fe_2(SO_4)_3$	Wt. Cu_2O	Wt. Cu in Cu_2O	Wt. $Fe^{...}$ in 50cc of Solution.	Grm Cu Extracted.	Residue.	Grm $Fe^{...}$ in 50cc of Solution after Extraction.	Total Amount Iron in 50cc	Duration.
1	1:2	0.1913	0.1592	0.2809	all	.....	0.1240	0.2809	4 hrs.
2	1½:2	0.2869	0.2388	0.2809	all	.....	0.1717	0.2809	4 "
3	3:2	0.5739	0.4776	0.2809	0.4302	brown	0.2352	0.2347	4 "
4	6:2	1.1478	0.9552	0.2809	0.4443	red	0.2219	0.2210	4 "
5	10:2	1.9354	1.609	0.2833	0.4723	.....	0.202	0.205	5 hrs. 40 min.
6	1:1	0.3661	0.3206	0.2822	all	.....	0.2550	0.2822	several min.
7	1:1	0.7322	0.6412	0.2822	all	.....	0.2583	0.2822	" "
8	1:1	0.732	0.6412	0.2822	all	.....	0.2709	0.2822	1 hour
9	1:1	0.805	0.705	0.2822	0.2780	.....	0.2368	0.2822	several min.

In the first experiment there was an excess of ferric sulphate present. All the copper present was dissolved, and an amount of iron reduced which was less than that computed by the equation above. The same is the case in experiment 2.

In experiment 3 the amount of iron required by the equation was not present. Therefore, after reducing all the iron the reaction was carried a step farther, and some iron was precipitated. With cuprous oxide there was never as much as one-half of the iron precipitated. It was also found that the iron still in solution was in the ferrous form. This fact, and the presence of ferrous iron in the precipitate makes the following process probable:

1. Copper is first oxidized: $Cu_2O + Fe_2(SO_4)_3 = 2CuO + CuSO_4 + 2FeSO_4$.

2. $CuO + FeSO_4 = CuSO_4 + FeO$.

Equation 2 has already been tested, and it was found later that cuprous oxide and ferrosulphate scarcely have any effect on each other.

In experiment 5 the amount of cuprous oxide was increased with the result that more iron was precipitated. In order to test the equation,

$Cu_2O + Fe_2(SO_4)_3 + H_2SO_4 = 2CuSO_4 + 2FeSO_4 + H_2O$,

more exactly, the next experiments were made with some oxide obtained from Kahlbaum. It contained 87.6 per cent Cu instead of the theoretical amount 88.8 per cent. In experiments 6, 7, 8 and 9 cuprous oxide and ferric sulphate were present in equivalent amounts. The solution took place so rapidly that all the copper was dissolved before the bottle could be corked and placed in the thermostat. These experiments show that when air is more completely excluded, results can be obtained that agree better with values calculated from the formula. In No. 6, for example, in which more than 50 cc. of air was present, the result agrees with the formula only to 10 per cent, while in No. 9 it agrees to 3 per cent. In the last case the bottle contained only 15-20 cc. of air, and the solution was effected by shaking in the hand for a few minutes. The amount of oxygen present in this amount of air could oxidize 0.04 gram of iron, which fully accounts for this discrepancy. The experiments show then that the above equation is correct.

It still remained to investigate the effect of copper sulphate and ferro sulphate on cuprous oxide. Fifty cc. of a solution containing 0.600 gram Cu were shaken eight hours with 4 grams of Kahlbaum's cuprous oxide. The amount of copper in solution was then found to be 0.557 gram, or 0.04 gram less than at the start. On account of the small difference it seems probable that the decrease is due to impurities in the copper oxide, so that these substances have no effect on each other, or at least only a very slight one. A similar result was obtained with ferro sulphate. 100 cc. of a solution containing 0.7466 gram iron were shaken three hours at 80°, with about 2 grams of cuprous oxide; 0.7086 gram ferrous iron was then found in the solution. The small amount of iron thrown out is apparently due to impurities also.

The results of the experiments with cuprous oxide are:

1. Cuprous oxide reduces ferric sulphate to ferrous sulphate according to the equation,

$Cu_2O + Fe_2(SO_4)_3 + H_2SO_4 = 2CuSO_4 + 2FeSO_4 + H_2O$,

and both ferrous and ferric iron is precipitated.

2. Cupric sulphate does not act on cuprous oxide.

3. Ferrous sulphate does not act on cuprous oxide.

Experiments with Cuprous Sulphide.

The equation which is given for the action of ferric sulphate on cuprous sulphite is the following:*

$Cu_2S + 2Fe_2(SO_4)_3 = 2CuSO_4 + 4FeSO_4 + S$.

The object of this part of the investigation was to test this equation.

The sulphide first used was Merk's, which came in the form of square rods. This was ground up in a mortar and shaken through a No. 80 sieve (80 meshes per inch). Analysis gave the following results:

	Found.	Theoretical Amount.
Cu	78.4%	79.80
S	21.5%	20.14

For the first experiments 50 cc. of the stronger solution of ferric sulphate were used. The following table gives the result:

Ratio of Cu_2S to $Fe_2(SO_4)_3$	Grm Cu_2S	Grm Cu in Cu_2S	Grm Fe in the Solution	Duration of Exp.	Grm Cu Dissolved.	Grm Fe Reduced.	Computed Amt. Fe Reduced
1:2	2.052	1.609	2.833	¼ hr.	0.9600	1.675	1.69

A comparison of the amount of iron reduced, and the computed amount shows a fair agreement. Some cuprous sulphide was then prepared by precipitation of cupric sulphide from a copper sulphate solution and reduction in a Rose crucible in a stream of hydrogen. Table 5 gives the results obtained with this sulphide.

TABLE 5.

No.	Grm Cu_2S Used.	Grm Cu Contained in Cu_2S	Grm Fe in Solution.	Duration of Exp.	Grm Cu Dissolved.	Grm Fe Reduced.	Computed Amt of Fe Reduced	Vol. of solution.
1	0.876	0.699	0.2822	2 hrs. 5 min.	0.2280	0.285	0.402	50
2	1.752	1.399	0.2822	" "	0.2288	0.286	0.389	50
3	0.946	0.756	0.5644	¼ hr.	0.3168	0.5546	0.5578	100
4	0.946	0.756	0.5644	6 hrs.	0.5238	0.5645	0.5790	100

In experiments 1 and 2 the amount of copper dissolved should have reduced more iron than was present. This was caused by the oxygen of the air, as the two following experiments prove. Here the bottles were nearly completely filled, and the water used for making the solution of ferric sulphate was boiled. Under these circumstances the amounts of iron found agrees with those computed to about 1 per cent. The amounts found were still always smaller than computed, which may be attributed to the small amount of oxygen still present.

For the sake of completeness the experiments of table 6 were made to see if sulphuric acid has any effect on cuprous sulphide. Best conducting sulphuric acid was used.

TABLE 6.

Gram Cu_2S.	cc. H_2SO_4.	Duration of Experiment.	Temp.	Gram Cu Dissolved in 50 cc.
1.0	100	5¼ hrs.	80°	0.0085
0.5	50	5¼ hrs.	80°	0.0468

These results show that, in the presence of oxygen, cuprous sulphide is dissolved to a slight amount.

The following experiments were made to find whether any reaction takes place between cuprous sulphide and ferrous sulphate or copper sulphate: 100 cc. of a copper sulphate solution containing 1.194 grams copper were shaken six hours at 80°, with 5 grams of Merk's cuprous sulphide; 1.186 grams copper were then found in the solution, which is an inconsiderable decrease.

The ferrous sulphate used in the second experiment was made up with boiled water and contained 0.2849 g. iron in 50 cc. 100 cc. were shaken for 2¾ hours at 80°, with 0.923 g. cuprous sulphide. The solution was tested with hydrogen sulphide and found to contain no copper, and the analysis for iron gave a result agreeing to 0.3 per cent, with the original amount.

The results of these experiments are:

1. The verification of the equation,

$Cu_2S + 2Fe_2(SO_4)_3 = 2CuSO_4 + 4FeSO_4 + S$.

2. The $FeSO_4$ formed has no effect on cuprous sulphide.

3. The $CuSO_4$ formed has no effect on cuprous sulphide.

4. Sulphuric acid dissolves cuprous sulphide in the presence of oxygen very slowly. The presence or absence of sul-

* See Borchers "Elektrometallurgie."

phuric acid in the solvent is therefore of very little consequence as far as Cu_2S is concerned.

Experiments with CuS.

The following seems to be the simplest reaction that can take place between copper sulphide and ferric sulphate:

$$CuS + Fe_2(SO_4)_3 = CuSO_4 + 2FeSO_4 + S.$$

The two experiments of table 7 were made to test this equation. The copper sulphide used was prepared from copper sulphate by precipitation with hydrogen sulphide.

Table 7.

No.	Grm CuS Used.	Grm Cu in CuS	Grm Fe in Solution.	Temp.	Duration of Exp.	Grm Cu Dissolved.	Grm Fe Reduced.	Calculated Amt. of Iron Reduced.
1	0.4824	0.3206	0.5644	80°	6 hrs.	0.2495	0.3520	0.4393
2	1.053	0.6995	0.2822	80°	2 hrs.	0.2377	0.2798	0.4186

In experiment 1, where the bottle was nearly full, and therefore not much air was present, the amount of iron reduced was less than that computed by the above equation, and in experiment 2, where only 50 cc. of the solution were used the discrepancy was still greater. In one case the residue was treated with carbon bisulphide and filtered. After evaporating a small amount of sulphur was left behind, proving that sulphur is set free in the reaction, and that so far at least the above equation is correct. If this equation is correct, however, the excess of copper must have been dissolved some other way. The following experiment showed that this excess was due to the oxygen of the air oxidizing copper sulphide to sulphate. In a 100 cc. bottle containing 50 cc. water and 1 gram copper sulphide the air was replaced by oxygen. After 5½ hours at 80° 0.171 gram copper was dissolved. Table 8 gives the results of experiments with sulphuric acid, copper sulphate and ferro sulphate:

Table 8.

Solvent.	Volume.	Wt. CuS Used.	Duration of Experiment.	Gram Cu Dissolved in 100 cc. of Solvent.
H_2SO_4 Sp gr. 1.2....	100 cc.	1.00	3 hrs.	0.0688
1.15% $CuSO_4$ Sol....	100 cc.	1.00	6 hrs.	0.079
0.55% $FeSO_4$ Sol....	100 cc.	1.00	6 hrs.	0.071

In all cases about the same amount of copper was dissolved, which shows that it was due to the oxygen present. Copper sulphate is therefore not dissolved by these reagents.

Experiments with Iron Oxide

Many copper ores contain iron, which is changed over to the oxide on roasting. It was therefore of interest to see if iron oxide is dissolved by ferric sulphate. 2.25 grams Fe_2O_3 were shaken for about an hour at 80°, with 50 cc. of a solution that contained 2.83 gr. iron. There was also some free acid present that came from the ferric sulphate. The solution was then analyzed and 2.79 gram iron found. A similar experiment was made with ferric hydrate freshly precipitate from 10 cc. of a 5 per cent solution. It was washed till the wash water gave no reaction for sulphuric acid, and was then shaken with 50 cc. of a solution containing 0.282 gram iron. The residue was then filtered off and well washed. It was found in dissolving some of this residue in hydrochloric acid and testing with barium chloride that some sulphate was present, indicating a basic salt. The reaction that takes place between Fe_2O_3 and $Fe_2(SO_4)_3$ is therefore to precipitate iron from the solution.

The Precipitated Sulphate.

Since sulphur is liberated from sulphide ores in the process of leaching, it was necessary to see whether this can be oxidized to sulphuric acid by ferric sulphate. In order to obtain sulphur in the same state as that liberated by leaching, some cuprous sulphide was warmed four times with fresh portions of 6 per cent ferric sulphate solution. The residue, which consisted mostly of sulphur, was washed, dried and then shaken with a new sample of 50 cc. of the same solution for about five hours at 80°. This solution contained 213.1 grams SO_4 per 1; after shaking with free sulphur 216.0 grams SO_4. The ferric sulphate therefore oxidized a very inconsiderable amount of sulphur; and therefore this reaction can have no significance for this process.

Experiments with SO_2

Some experiments were made on the relative efficiency of reducing ferric sulphate with SO_2, and with this gas largely diluted, as in the case of furnace gasses. Leading the pure gas (taken from a bomb) through ferric sulphate at 80°, the amount of iron reduced was 8.9 per cent of that which would have been reduced, if all the SO_2 had been used up, as was found by titrating the iron with permanganate after driving out the SO_2 by CO_2 gas. On diluting the SO_2 with air so that it amounted to about 10 per cent of the total amount, 5 per cent iron was reduced. The furnace gases might, therefore, be used to reduce the small amount of ferric sulphate still remaining after having treated the ore, as the solution from which the copper is to be precipitated should contain no ferric salt.

Experiments with a Copper Ore.

Analysis of the ore gave the following results:

Cu	29.99%
Fe	27.89%
S	33.32%
SiO_2	9.75%
	100.95

Leaving out the silicon dioxide the relative amounts of copper, iron and sulphur are given in table 9, and the composition of copper pyrites is also tabulated for the sake of comparison.

Table 9.

	Contained in $CuFeS_2$.	Contained in the Ore.
Cu	34.4%	32.9%
Fe	30.6%	30.6%
S	34.9%	36.5%

The composition of the ore corresponds therefore closely to that of copper pyrites. The first experiments showed that the ore was scarcely attacked by a 5 per cent solution of ferric sulphate. The powdered ore was therefore shaken through a No. 80 sieve and roasted several hours in an enamel plate over a Bunsen burner. It was then found to contain 28.8 per cent Cu and 18.9 per cent S. From the previously determined ratio of copper to iron the amount of iron present in the roasted sample was computed to be 27.0 per cent.

Some of the iron and copper has been oxidized, so that 7.6 per cent of the ore was copper sulphate, and 2.3 per cent iron sulphate. In table 10 the process of solution can be followed: 5.351 grams ore and 50 cc. of a ferric sulphate solution containing 2.833 grams iron were used. The ore contained 1.54 grams copper.

Table 10.—Temperature 83° C.

	After ¼ hr.	After 1 hr.	After 2 hrs. 10 min.	After 6 hrs.
Iron Cu dissolved....	0.9045	1.047	1.118	1.163
Per cent Cu dissolved.	58.7	68.3	72.5	75.3
Grams Fe dissolved...	0.237	0.407	0.470	0.440
Per cent Fe dissolved.	16.5	27.2	31.4	29.4
Grams Fe$^{\cdots}$ present..	2.080	2.001	1.908	1.751

These results show that not much more than 75 per cent of the copper could be dissolved from this sample. The curves in Fig. 1 represent this table graphically. Curve 1 represents the ferric sulphate present. The straight line below curve 1 represents the original amount of copper in the ore. Curves 2 and 3 represent the copper and iron dissolved, respectively.

A second set of experiments was made with a smaller amount of ore, and the same volume of solvent. In this case a little more copper was dissolved, as the following table and curves show.

2.398 grams ore was used, containing 0.6899 gram Cu and 0.6483 gram Fe. The solvent was the same. Table 11 and Fig. 2 give the results.

TABLE 11.—TEMPERATURE 80°.

	After ¼ hr.	After 55 min.	After 1 hr. 55 min.	After 6 hrs. 15 min.
Iron Cu dissolved ...	0.4115	0.4700	0.4797	0.5415
Per cent Cu dissolved.	59.6	68.0	69.5	78.5
Gram Fe dissolved..	0.107	0.195	0.191	0.239
Per cent Fe dissolved.	16.5	30.0	29.8	36.9
Gram $Fe^{\cdots}$ present.	2.312	2.033	2.024	1.819

In Fig. 2, curve 1 represents the ferric sulphate present, curve 2 the copper dissolved, curve 3 the iron dissolved, while the straight line represents the copper in the ore at the start.

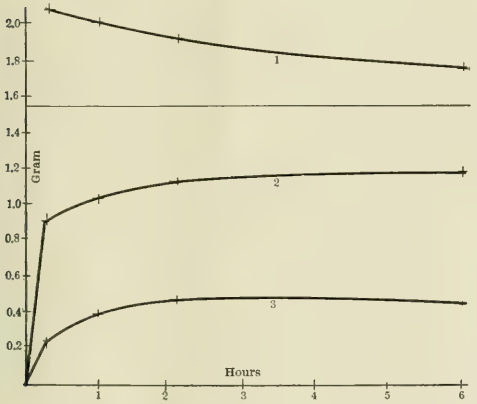


FIG. 1.—CURVE 1, FERRIC SULPHATE PRESENT; CURVES 2 AND 3, COPPER AND IRON DISSOLVED RESPECTIVELY.

These results confirm those previously obtained. Experiments were then performed to see if more of the copper could be dissolved out of the ore already treated by using fresh portions of solvent. Three bottles were filled with 100 cc. of a 6 per cent solution of ferric sulphate and 12 grams of ore, and shaken for two hours at 80°. The amounts of copper dissolved were 65.6 per cent, 66.2 per cent, and 66.2 per cent. The solution was siphoned off and 100 cc. fresh solvent added

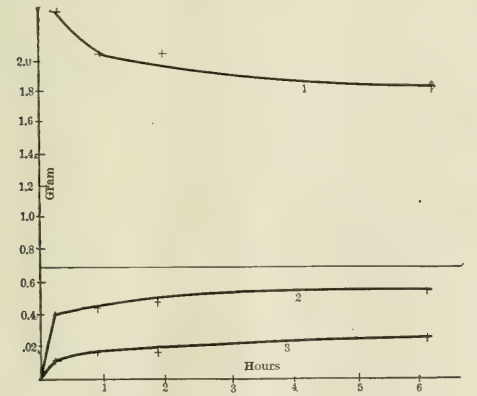


FIG. 2.—CURVE 1, FERRIC SULPHATE PRESENT; CURVE 2, COPPER DISSOLVED; CURVE 3, IRON DISSOLVED.

to each bottle. They were then shaken for different lengths of time, as shown in table 12.

	Bottle No. 1. Shaken 1 hr.	Bottle No. 2. Shaken 2½ hrs.	Bottle No. 3. Shaken 5 hrs.
Grm. Cu dissolved	0.193	0.256	0.350
Per cent Cu dissolved in this and previous treatments	71.2	73.6	76.3

The bottles were again filled and No. 1 was shaken one hour, No. 2 two and one-half hours, and No. 3 five hours. This increased the amount dissolved in No. 1 to 73.5 per cent, in No. 2 to 76.4 per cent, and in No. 3 to 79.6 per cent. The last bottle was shaken again with fresh solvent for five hours, which increased the amount of dissolved copper to 81 per cent. The residues from these experiments were collected and roasted again. It was found that by this means 91.8 per cent of the copper still remaining in the ore were dissolved by the solvent in an hour. For this reason the ore used in the above experiments was roasted again. The copper then amounted to 30.2 per cent. Six grams of this ore, when shaken one hour at 80°, with 100 cc. of approximately 6 per cent ferric sulphate solution. This dissolved 1.702 grams, or 93.9 per cent of the copper present. In five hours, under similar conditions, 98.9 per cent copper was dissolved.

These experiments show that copper can be dissolved by ferric sulphate pretty completely as soon as the ore is sufficiently roasted. The question is what are the compounds formed by roasting, which are so much more soluble than the unroasted ore. It seems that this is due to the formation of copper oxide. If this is the case, just as much copper would be dissolved by sulphuric acid. To test this conclusion 6 grams of the ore used in the last experiments were shaken with 100 cc. of sulphuric acid, sp. gr. 1.2, for five hours. This dissolved 1.71 grams, or 97.7 per cent. It was found, however, in the study of cuprous sulphide, that this is easily extracted by ferric sulphate, and this is exactly what was under investigation in these experiments, combined with the sulphide of iron. It must be this double combination therefore that prevents the copper from being extracted by the ferric sulphate.

The amount of sulphate was slightly increased by the second roasting. 8.9 per cent of the ore was copper sulphate, which corresponds to 1.8 per cent sulphur. As the total amount of sulphur was found to be 8.2 per cent, there must have been a considerable amount present in the form of sulphide. It could not be determined, however, whether it was combined with the iron or the copper. It was not present in iron sulphate, as only 0.4 per cent of the iron was in the form of sulphate.

The results of this part of the investigation may be summed up as follows:

1. Copper pyrites is not appreciably attacked by ferric sulphate.

2. Roasting so changes the ore that nearly all the copper can be extracted either by sulphuric acid or by ferric sulphate. This makes it seem probable that the roasting changes the copper largely over to the oxide.

THE ELECTROLYSIS.

The electrolysis comprises two reactions, the reduction of the copper on the cathode and the oxidation of iron at the anode. These were investigated separately. The vessel used was a copper voltameter jar divided into three narrow compartments by two clay diaphragms made fast to the glass sides with paraffin. The anode and cathode were in the outer compartment, while the inner one prevented diffusion from one electrode to the other.

In the experiments on the deposition of copper a lead plate was used as anode, and the anode compartment was filled with sulphuric acid. The cathode compartment was filled with a solution of the following composition:

5 per cent ferrous iron.
3.5 per cent copper.
2.5 to 3 per cent sulphuric acid.

The same solution was contained in the middle compartment. During electrolysis the liquid in the cathode compartment was stirred by a current of carbon dioxide.

The object in these experiments was to determine how poor the solution may become in copper without affecting the character of the copper deposited at a given current density. This was to be determined for different current densities. For this purpose the gain in weight of the copper cathode was compared with the copper deposited in a copper voltameter. Table 13 gives the results obtained with a current density of 0.98 ampere per square decimeter.

Table 13.

Time in Hours.	Cu Deposited in Voltameter for ½ hr	Cu Deposited in Cell for ½ hr.	Per Cent Yield.
½	0.3346	0.3301	98.65 per cent.
1	0.3346	0.3328	99 45 "
1½	0 3377	0.3356	99.40 "
2	0.3385	0.3384	100 "
2½	0.3474	0.3469	99.97 "
3	0.3397	0.3399	100 "
3½	0.3321	0.3312	99.75 "
4	0 3340	0.3341	100 "
4½	0.3399	0.3352	.....

After four hours the copper commenced to be spongy. The cathode solution was then analyzed and was found to contain 0.72 per cent copper.

In another similar experiment with the same current density, the copper did not begin to be spongy till the strength of the solution had reached 0.38 per cent copper.

Table 14 gives the results with a current density of 1.8 ampere per square decimeter.

Table 14.

Time in Hours.	Cu Deposited in Voltameter in ½ hr.	Cu Deposited in Cell in ½ hr.	Yield.
½	0.6049	0.5934	98.1 per cent.
1	0.6322	0.6157	97.4 "
1½	0.6123	0.6086	99.4 "
2	0.6038	0.6020	99.7 "

At the end of the second hour the copper began to be spongy. The electrolysis was therefore discontinued and the solution in the cathode compartment analyzed. It contained 0.98 per cent Cu.

The current density was then reduced to 0.47 ampere per square decimeter, and the electrolysis continued, with the results given in table 15.

Table 15.

Time in Hours.	Cu Deposited in Voltameter in ½ hr.	Cu deposited in Cell in ½ hr.	Yield
½	0.1689	0.1693	100 per cent.
1	0.1589	0.1547	97.35 "
1½	0.1611	0.1595	99.02 "
2	0 1646	0.1622	98.55 "
2½	0.1639	0.1639	97.7 "
3	0.1658	0.1669	100 "

Here the copper came down in good form till the concentration of copper was 0.05 per cent in the solution.

Two other experiments were carried out with current densities of 3.4 amperes and 2.6 amperes per square decimeter, respectively. In the first case the copper was deposited in a spongy form immediately. The same was true in the second case, though not in so marked a manner. Some of the spongy copper was tested for iron, but this impurity was not present.

The results are best shown by Fig. 3 in which the abscissae represent the current density, and the ordinates the concentrations of the copper solution when the copper began to be spongy.

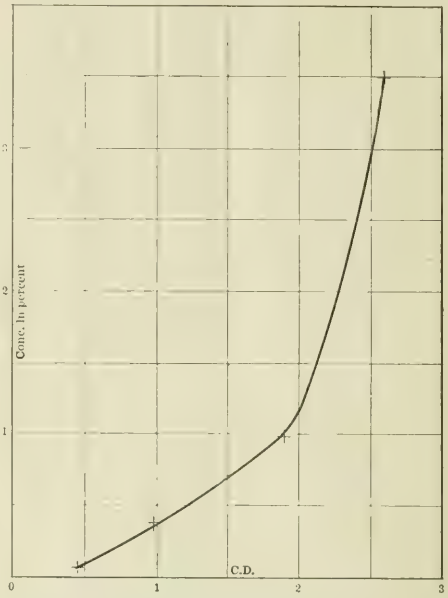


FIG. 3.—CURVE SHOWING THE CONCENTRATION OF THE COPPER SOLUTION FOR WHICH THE COPPER BEGINS TO BE SPONGY AT A CERTAIN CURRENT DENSITY.

Oxidation of the Anode.

In these experiments the anodes consisted of round carbon rods 2 cm. in diameter and 15 cm. long. Each rod stood in a clay cylinder 12.5 cm. high and 4 cm. in diameter, which were filled with the anode solution. The clay cylinder was placed in a large glass vessel. A cylindrical sheet of copper served as cathode, and copper sulphate as the catnodic solution. Several such cells were connected in series and electrolyzed. From time to time a cell was disconnected and analyzed, while the electrolysis of the rest was continued. The amount of iron oxidized was compared with a copper voltameter connected in series with the cells. The amount of iron oxidized was determined by analyzing the amount of ferrous iron in the anode compartment before and after the electrolysis. The amount of ferrous iron diffused into the cathode compartment was determined and allowed for.

Table 16 gives the results with a current density of 0.48 ampere per square decimeter. The current was 0.36 ampere, and the surface of the anode 0.76 square decimeter.

Table 16.

Time.	Gr Fe" in Anode Compartment.	Gr Fe" Diffused from Anode Compartment.	Gr Fe" Oxidized.	Gr Cu in Voltameter.	Gr Fe Representing 10% Yield.	Yield of Oxidiz'd Iron.
						Per Cent
9:15	2.776	.....	.....	.....	.....	....
10:15	1 933	0.0671	0.776	0.419	0 738	105
11:15	1.451	0.1122	1.213	0.7642	1.344	90
12:15*	1.058	0.104	1.614	1.143	2 015	79.5
2:30	0.6676	0 1815	1.926	1.581	2.785	69
3:30	0 2446	0.1724	2.359	1.971	3 47	68
4:30	0.1044	0.189	2.483	2.417	4.25	58.3

* Electrolysis interrupted from 12:15 to 1:30.

In this series, as in others, the yield for the first period amounted to more than 100 per cent. It is possible that the

oxygen absorbed in the carbon may have been the cause for this. These results are shown graphically in Fig. 4.

Table 17 contains the results of the second series, with a current density of 0.26 ampere per square decimeter, while Fig. 5 shows the results graphically.

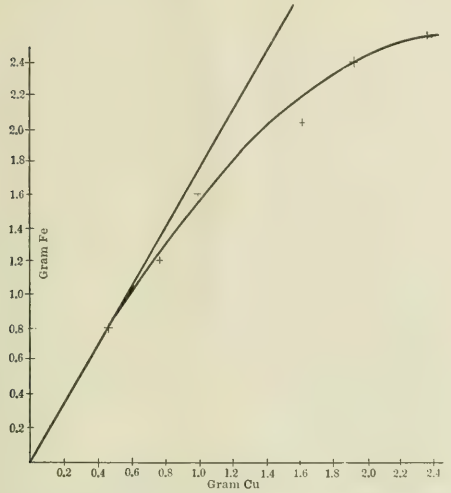


FIG. 4.—THE ABSCISSAS ARE THE GRAMS Cu IN THE COPPER VOLTAMETER, THE ORDINATES IN Gr Fe OXIDIZED. THE STRAIGHT LINE GIVES THE THEORETICAL YIELD ACCORDING TO FARADAY'S LAW. THE BENT CURVE SHOWS THE RESULTS OBTAINED EXPERIMENTALLY, C.D. = 0.47.

TABLE 17.

Time.	Gr Fe in Anode Compartment.	Gr Fe diffused from Anode Comp.	Sum of Preceding two Columns.	Gr Iron Oxidized.	Cu Precipitated in Voltameter.	Gr Iron Representing 100 per ct. Yield.	Yield.
							Per Ct.
10:23	2.791	.....	.....	.....	.....	.....	.....
11:30	2.097	0.613	2.110	0.681	0.3641	0.641	106
11:45	1.629	0.055	1.684	1.107	0.5780	1.02	108
2:35	1.219	0.060	1.279	1.512	0.8715	1.54	98
3:40	0.7549	0.0953	0.8502	1.941	1.3367	2.35	83
4:20	0.4337	0.1060	0.5397	2.251	1.6134	2.84	79
5:05	0.2715	0.1249	0.3964	2.395	1.9300	3.40	70

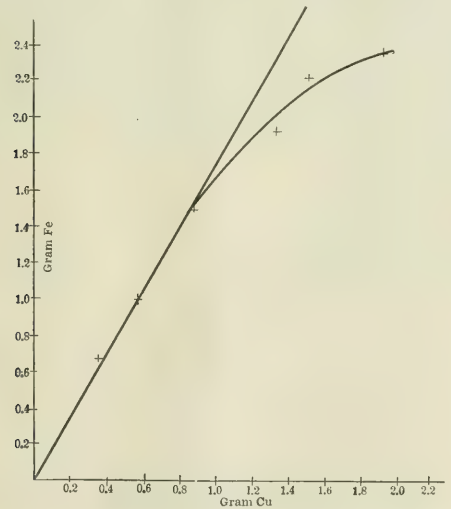


FIG. 5.—THE SAME AS IN FIG. 4, BUT C.D. = 0.26.

A third experiment was carried out with a current density of 0.53 ampere per square decimeter, the results of which are tabulated in table 18. At the end of the first and last periods two cells were taken out together and analyzed, in order to see how well they would agree when electrolyzed for exactly the same length of time. The results for the first period agreed to 6 per cent, and for the last to 4 per cent.

TABLE 18.

Time	Gr Fe in the Anode Compartment	Gr Fe Diffused Away.	Sum of two Preceding Columns.	Gr Fe Oxidized.	Cu Precipitated in Voltameter.	Gr Fe Representing 100 per ct. Yield.	Yield.
							Per ct.
9:00	2.779	.....	.....	.....	.....	.....	.....
9:40	2.116	0.097	2.213	0.566	0.3273	0.559	101
	2.072	0.107	2.179	0.600			107
10:55	1.256	0.114	1.370	1.409	0.8895	1.52	92.6
11:45	0.786	0.152	0.920	1.659	1.2478	2.14	77.6
1:48	0.207	0.267	0.474	2.305	2.0820	3.56	64.8
	0.108	0.278	0.386	2.39			67.2

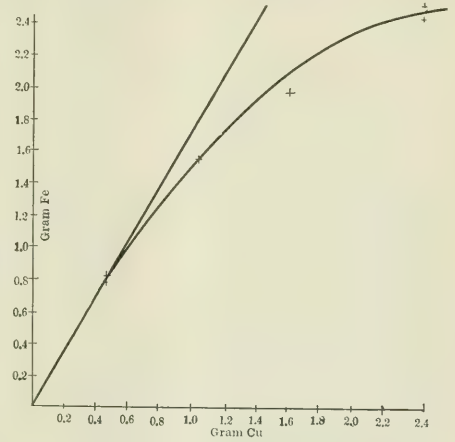


FIG. 6.—THE SAME AS IN FIG. 4, BUT C.D. = 0.53.

As Fig. 6 shows, the deviation from Faraday's law becomes marked at about the same time for this current density as for that of the preceding runs, showing that a variation from 0.3 ampere to 0.5 ampere per square decimeter has no noticeable effect on the current yield. Large deviations from Faraday's law were accompanied by a strong evolution of gas.

In all these experiments the yield for the first period amounted to more than 100 per cent. It seems probable, therefore, that if the disturbing causes were removed, the yield would not fall much below 100 per cent. At the end of the first period the solution contained 2.1 per cent ferrous sulphate. Therefore, the conclusion may be drawn that starting with a solution containing 5 per cent ferrous iron, this may be oxidized with approximately 100 per cent yield, till the solution contains only 2 per cent of ferrous iron, using a current density from 0.3 to 0.5 ampere per square decimeter. When the solution contains between 2 per cent and 1 per cent of oxidizable iron, the yield would still be about 90 per cent. When the concentration is still more diminished, the evolution of gas becomes strong and the yield falls off correspondingly.

AMERICAN INSTITUTE OF MINING ENGINEERS.—The eighty-seventh meeting of the Institute will be held in September in the Lake Superior region, and arrangements will be made for a subsequent visit of members to St. Louis in the last week of September, with a supplementary session at the World's Fair. Headquarters for members of the American Institute of Mining Engineers and the American Society of Mechanical Engineers will be maintained in the Mining Building.

WET METHODS OF EXTRACTING COPPER.

In a recent paper, presented to the *American Institute of Mining Engineers*, considerable information is given by Mr. Charles H. Jones on the methods of leaching and precipitating copper, in use at Rio Tinto in Spain. This paper is of special interest and value, in view of the fact that most of the information heretofore published pertaining to these methods has become obsolete.

The ore treated at Rio Tinto is a massive iron pyrite containing up to 3 per cent of copper, which has been disseminated through the mass by a secondary enrichment. The well-known method adopted for the extraction of the copper consists simply in allowing huge heaps of the mineral to oxidize under the influences of moisture and air, and subsequently washing out the copper sulphate as soon as it is formed, by running water through the heap.

The successful and economical application of this system depends largely on the state in which the copper occurs in the mineral. If it exists as chalcopyrites, $CuFeS_2$, the copper will not oxidize by simple exposure to the air. If the copper is in the form of CuS, the oxidation proceeds very slowly. The best form for solution is Cu_2S or copper glance, which constitutes the bulk of the copper in Rio Tinto pyrite.

The following reactions take place during oxidation. When the mineral is exposed to free access of air and moisture, some ferrous sulphate is formed as follows:

(1) $FeS_2 + 7O + H_2O = FeSO_4 + H_2SO_4$.

The ferrous sulphate thus formed becomes readily oxidized by the air to ferric sulphate.

(2) $2FeSO_4 + H_2SO_4 + O = Fe_2(SO_4)_3 + H_2O$.

and it is due to the action of this ferric sulphate on the copper sulphides that the copper is rendered soluble, as represented by the following equations:

(3) $Fe_2(SO_4)_3 + Cu_2S = CuSO_4 + 2FeSO_4 + CuS$.

(4) $Fe_2(SO_4)_3 + CuS + 3O + H_2O = CuSO_4 + 2FeSO_4 + H_2SO_4$.

The reaction (3) takes place fairly rapidly and causes half the copper to go into solution within a few months, while the reaction (4) proceeds much more slowly, and requires, under the most favorable conditions, about two years to extract 80 per cent of the remaining half of the copper.

In practice the method adopted to bring about the desired oxidation is as follows: A site is chosen for the formation of the heap where the ground is sufficiently concave and sloping to enable the copper liquor that is formed to collect and run out at the base of the heap. On the ground is first arranged a network of air-flues made of rough stones and having an internal diameter of 12 inches. Vertical chimneys, 50 feet distant from one another, are built in the same manner and connect with the ground flues. Care is taken that the mouth of the ground flues are kept open and not covered by the ore. The mineral, the lump portion of which has been passed through jaw-breakers to be reduced to pieces not larger than from 2 to 3 inches across, is now tipped from side-tip wagons at the highest part of the selected side over and around the stone flues. "Lump" and "fines" are alternately dumped until the height of the mass at the edge is about 30 feet, the upper surface of the mineral being kept level. A heap of this form approximately contains 100,000 tons of ore.

As the mineral is added, the building of the stone chimneys keeps pace, in order to have a clear opening to the top of the heap. The surface of the heap is formed into squares by means of ridges of the mineral, the size of these squares depending on the porosity of the heap. The function of these ridges is to enable the water to be run on locally over the surface of the heap in order to insure that all parts are equally washed, and that the water does not run through the heap in channels. A system of gutters is also arranged so that the water can be run on to all parts of the mass. As the heap is being formed, water is run on, and the copper sulphate existing in the mineral is extracted; also, the water provides the moisture for the oxidation to take place in accordance with the equations given above. The mineral in the heap is then allowed to oxidize, which it does pretty rapidly, as evidenced by the heat produced, the temperature in the chimneys rising to from 170° to 180° F. As the temperature increases, the surface-openings of the chimneys may be closed in order to allow the oxidation to spread through the heap.

The surface gradually shows a brownish coloration due to the dehydration of the buff-colored basic ferric salt that forms on the top of the mass and its gradual heating up may be noted by this drying action. The greatest care must be taken not to allow the heap to fire, for if once started it is very difficult to extinguish it. When the oxidation has proceeded as far as it is safe to allow it, water is run on at the rate of about 50 cu. m. per hour, until the soluble copper is leached out; the heap is then allowed to re-oxidize and the washing is repeated. After about a year has elapsed the surface requires "retilling," and the squares are re-arranged so that the places where the ridges were before are now the middles of the squares; the gutters also are shifted. At the edge of the heap for a distance of some yards the mineral which has become cemented holds a considerable quantity of copper salts and is dug down into terraces in order that this copper may be extracted by washing. When the copper is reduced to 0.3 per cent, the heap is considered washed and the mineral, containing 49.5 per cent of sulphur, is removed and exported as "washed sulphur ore" and utilized for the manufacture of sulphuric acid. Fig. 1 shows the surface of the heaps arranged for washing.

FIG. 1.—THE SURFACE OF THE HEAPS ARRANGED FOR WASHING.

Successful heap-washing depends on the efficient ventilation of the mass, the trouble usually being a too great excess of "fines" produced in mining the ore, which cement hard and clog up the air passages.

The copper liquor as it runs from the heap contains some ferric iron in solution, which is very objectionable. In order to remove the ferric iron the liquor is run over a smaller heap of fresh mineral known as a "filter bed" which reprecipitate." These cementation tanks are arranged in series on the slope of a hill, the liquor passing backwards and forwards until it is discharged from the lowest tank of the series free from copper.

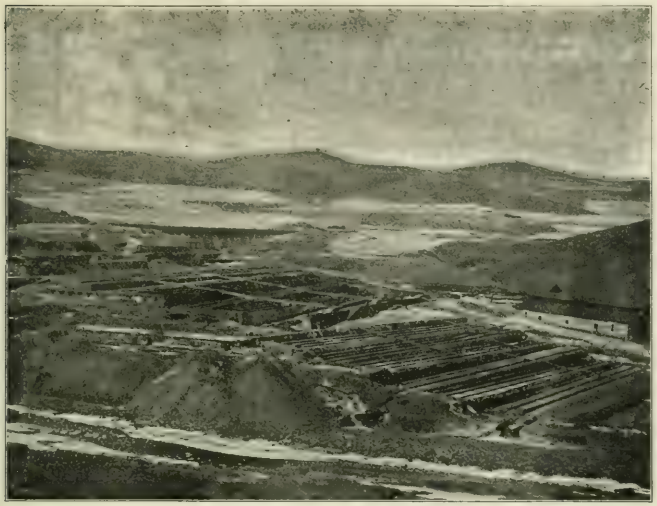


FIG. 2.—PRECIPITATING TANKS AND THE MASONRY DAM FORMING RESERVOIR FOR THE PERCOLATION OF THE COPPER LIQUOR.

Each series consists of three tanks in parallel arranged so that the liquor can be divided up and passed along as many tanks as necessary, depending on the quantity of liquor that is being run through and on the varying temperature of the liquor with different seasons: the hotter the solution, which in summer reaches 100° F., the faster the rate of precipitation. Each tank is about 320 feet long, 5.5 feet wide, by 2.25 feet deep, and has a slope varying from 2 per 1,000 in the first series to 11 per 1,000 in the last, the reason for the increase in slope being, that as the liquor becomes impoverished in copper the free acid present is more active in wastefully dissolving the pig iron, an action which is considerably diminished by increasing the velocity of the liquor by means of the increased slope of the tanks. The tanks themselves are made of 9-inch by 3-inch boards attached to wooden frames set in cement constituting a wall supporting the sides of the tanks. A view of the tanks showing the method of removing the cement copper is shown in Fig. 3.

duces the ferric iron. This "bed" is laid inside a reservoir formed by a masonry dam across a small ravine, and the liquor, after percolating through the mineral, remains in contact with it until it is required to be drawn off to the precipitating tanks. When the mineral is fresh, the reduction of the ferric iron takes place rapidly, due to the Cu_2S as shown by equation (3), but the iron pyrite itself has an effective reducing action on ferric iron in solution according to the following equation:

(4) $7Fe_2(SO_4)_3 + FeS_2 + 8H_2O = 15FeSO_4 + 8H_2SO_4$.

A general view of the precipitating tanks and the masonry dam forming the reservoir for the percolation of the copper liquor is shown in Fig. 2. The principal constituents of the liquor as it enters the cementation tanks are as follows, the figures given representing the grams per cu. m. or units per million parts: Copper, 4,000; ferric iron, 1,000; ferrous iron, 20,000; free sulphuric acid, 10,000; and arsenic, 300. The large quantities of ferrous iron and free sulphuric acid are due to the fact that the waste liquor from the cementation tanks after the copper has been precipitated ("salida" liquor as it is called), is pumped back and used for washing the heaps in addition to fresh water, and consequently these solutions tend to become concentrated. The liquor is then run from the reservoirs at about 300 cu. m. per hour through the precipitation tanks over pig iron in order to precipitate the copper in the form of so-called "cement copper" or "copper

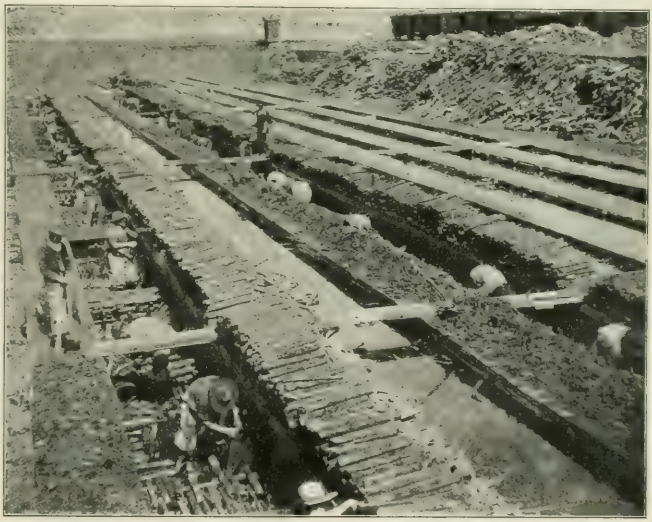


FIG. 3.—METHOD OF REMOVING THE CEMENT COPPER.

No metal is used in the construction, hard wooden pegs being employed to attach the boards to the frames. The spaces between the boards are carefully calked with oakum and pitch in order to render the tank water-tight. At each end of the tank is an arrangement by which a door can be dropped in and luted so as to cut out that particular tank, and there are also wooden plugs that can be removed so that the liquor from that tank can be run off, thus allowing for the

removal of the precipitated copper. A few old boards are placed on the bottom of the tanks for their protection, and on these are piled up the pigs of iron which are laid across the tank at the bottom, the next layer being at right angles to the first, and so on until the tank is filled; each foot-length of the tank contains about one ton of iron.

The liquor is allowed to run through the system of tanks and needs no attention except to remove the precipitated copper and to add fresh iron. The "salida" liquor, containing from 15 to 20 grams of copper per cu. m., is allowed to run to waste, for the reason that about this copper-content the amount of iron required to precipitate the copper equals the value of the copper recovered. Daily some of the tanks are cleaned out by being closed as described above, the liquor meanwhile passing down the other tanks of the series; the liquor is run off into settling tanks, any copper in suspension being there recovered; all of the iron is removed from the tank and piled on to the dividing wall, at the same time the copper adhering to the iron is knocked off and thrown back into the tank.

The dirty-looking precipitate is then transferred to the cleaning and concentrating plant, the iron is replaced in the tank and the liquor again allowed to run through it. This crude precipitate, containing about 70 per cent copper, is thrown, a little at a time, on to a perforated copper plate placed at the head of a long launder or tank and is washed through the plate by a strong stream of water from a small nozzle. The material that does not pass through the screen consists of leaf-copper and small pieces of iron; this material is thrown into a heap and afterwards sorted over by girls who remove the pieces of iron. The precipitate that passes into the launder is repeatedly turned over against the stream of water, and by this simple means a concentration is effected.

The first few yards of the launder contain a red precipitate known as "No. 1 precipitate," containing 94 per cent copper and less than 0.3 per cent arsenic; following this is "No. 2 precipitate," containing 92 per cent copper and between 0.3 and 0.75 per cent arsenic, while below is the "No. 3 precipitate;" this is in a state of very fine division and contains on an average 50 per cent copper and 5 per cent arsenic. This last-named portion, which carries all the graphite from the pig, contains the bulk of the antimony and bismuth that is also precipitated from the liquors.

Classes Nos. 1 and 2 are removed to the drying sheds and are bagged for shipment to the refinery; the No. 3 precipitate is removed, moistened with acid liquors, made into balls by hand, and dried in the sun. These balls become cemented hard and can be readily transferred to the smelter, where they form part of the charge for the blast-furnaces and are run down to matte to be subsequently bessemerized, thus effectively removing the arsenic, antimony and bismuth that they contain.

The reactions that take place in the cementation tanks are given in equations 5, 6 and 7. The first reaction that occurs in the liquor running over metallic iron is the reduction of the ferric sulphate to ferrous sulphate, the final result being in accordance with the equation:

(5) $Fe_2(SO_4)_3 + Fe = 3FeSO_4$.

This action causes the consumption of the pig iron without any corresponding yield in copper, and consequently should be avoided as far as possible, by having all the iron in the ferrous state.

The second reaction is the precipitation of the metallic copper, brought about by electrochemical action. The iron becomes coated with copper, and thus the iron and copper in the acid liquor constitute a galvanic couple with a considerable difference of potential (or, in other words, a short-circuited galvanic cell.) It is due to the electrolytic action that the copper and all other metals present that are electronegative to iron will be precipitated. (In the language of the electrolytic dissociation theory the reaction is due to the high solution tension of iron, compared with that of copper.) The ultimate action of the precipitation may be chemically expresed by the following equation:

(6) $Fe + CuSO_4 = FeSO_4 + Cu$.

Besides the reactions above mentioned there is one which causes the liberation of hydrogen, as evidenced by the bubbles of gas that may be observed to arise in the tank liquor. This action, which causes a wasteful consumption of the iron, may be expressed as a final result by the following equation:

(7) $Fe + H_2SO_4 = FeSO_4 + H_2$.

These three equations constitute the main reactions that take place in the precipitating tanks.

While the liquor is fairly strong in copper, the copper is mostly precipitated in a coherent form, but in the later stages as the liquor becomes impoverished it is precipitated in a powdery state—a condition which is more effective in its galvanic action with the iron, and thus unfortunately causes a larger precipitation of arsenic and other impurities than in the earlier stages. In the later stages also the "solution reaction" of iron in sulphuric acid, as given in equation (7), goes on to a proportionately greater extent than does the precipitation of copper, and consequently the cost of pig iron in precipitating the copper varies inversely as the quantity of copper in the liquor.

By keeping careful watch on the reduction as far as possible of the ferric iron before the liquor enters the tanks, and by giving it sufficient velocity through the tanks, a strongly acid liquor such as given above during a year's working will not consume more than 1.4 units of pig iron (containing 92 per cent iron) to one unit of copper precipitated. A valuable check on the iron being consumed can easily be kept by the laboratory, by analyzing the liquors before entering and after leaving the tanks, and from these analyses the quantity of iron that is being consumed can be calculated.

PALLADIUM.

At the general meeting of the American Philosophical Society held recently in Philadelphia, a paper was presented by Mr. Joseph Wharton, whose remarks are suggestive, taken in connection with the article of Dr. Wohlwill printed in our present issue. The following abstract of Mr. Wharton's paper is taken from a recent issue of *Science*.

The rare metal palladium belongs to the platinum group, yet in some respects resembles silver also. It usually occurs as a companion to platinum and thus exists in many places, but in such extremely small quantity that until lately the reworking of platiniferous residues from the various mines supplied most of what appeared.

The prevailing scarcity of platinum now directs attention to palladium as a practicable substitute; for it has many of the good qualities of platinum, while its price is rather lower. Both platinum and palladium occur in all the numerous nickel mines found among the Laurentian and Huronian rocks in the province of Ontario, Canada; the quantity of each of these metals varying from a mere trace to one or more ounces per ton, the average for each metal being one-hundredth of an ounce per ton.

Those Canadian ores carry nickel, copper, silver, gold, platinum, palladium, iridium and rhodium. The percentages of the precious metals are extremely minute and the various processes by which all these metals are recovered are naturally complicated and delicate; yet, as approximately 300,000 tons of these ores are treated annually by the Orford Copper Company, which owns most of those mines, that company now produces about 3,000 ounces of palladium annually. The reports of the Canadian government upon the metallic and mineral resources of the Dominion have never mentioned palladium as one of these resources. It is not known in what condition the palladium exists in that region, but as platinum

has been found there in the form of platinum arsenide, it seems probable that palladium may occur in the same condition.

Among the valuable characteristics of this metal are its hardness, ductility and malleability; it is also so non-corrodible that a polished sheet of it may long remain exposed to chlorine and hydrogen sulphide gases without tarnishing or losing its polish.

RECENT METALLURGICAL PATENTS.

COPPER.

E. P. Clark (patent 959,670, May 10) suggests a treatment of the mixed ores of copper by which the carbonates, oxides and metallic copper are first leached out and passed as copper sulphate solution into depositing tanks where the copper is deposited by electrolytic or chemical means. The portion of copper present as sulphide in the ore remains in the ore, since it is insoluble. The ore is then washed from the leaching tank and passed over concentrators. The sulphides being the heavier part are easily separated and are then oxidized by roasting and added to the next charge of ore in one of the leaching tanks. It is thus only necessary to roast the actual sulphides contained in the ore and not the entire body of ore. The solution in the leaching tank is prepared as follows: Sulphuric acid is added to water until the gravity reaches 7½° to 8° Baume; sulphate of iron is added in the proportion of 1 to 1¼ per cent of the total weight of acid and water. This solution is passed into the leaching tank on top of the ore and filters through it slowly, coming away from the filter bottom as a blue solution of copper sulphate. In connection with this we may refer to the article on wet methods of extracting copper, published on another page of this issue.

L. E. Porter (patent 759,220, May 3) intends to increase the scope of the cyanide process. He first subjects the ore in the usual way to the action of an alkaline cyanide solution, thereby dissolving gold, silver, copper, etc. Gold and silver are precipitated by the ordinary method with zinc shavings. The resulting cyanide solution is treated with an acid, yielding copper cyanide precipitate and hydrocyanic acid which are separated from each other. The hydrocyanic acid solution is neutralized with an alkaline oxide, such as caustic soda, caustic lime or caustic potash, thereby producing an alkaline cyanide solution suitable for the repetition of the process described before. The cyanide copper precipitate is mixed with an alkaline solution, and the mixture is treated by electrolysis, whereby metallic copper is deposited and an alkaline cyanide solution obtained, suitable for the further treatment of ores.

GOLD.

Besides the last patent noticed above under copper, there was granted a patent to I. Anderson (759,493, May 10) for the treatment of waters flowing from mines or stamp mills, etc., and containing gold and silver ores in which copper or iron are also present. For the deposition of the precious metals, the treatment of the solution with lime in finely divided condition is recommended. In case the water does not contain copper or iron in addition to gold and silver, it is recommended to add either copper or iron or both to the solution before adding lime. Gold and silver are stated to be deposited in solid form and may be recovered by filtration.

ALUMINIUM.

To the long list of aluminium alloys, which are already more or less successfully used, another is added in a United States patent granted to S. Kneppel (patent 759,617, May 10). It consists of 6 parts of aluminium, 1 part of zinc and 2 parts of Babbit metal, by weight, the Babbit metal consisting of 96 parts tin, 8 parts antimony and 4 parts copper, by weight. This alloy is claimed to be suitable for the manufacture of vats, coolers, kegs, etc., for the manufacture, storage and transportation of lager beer.

CHROMIUM.

A. K. Eaton (patent 759,424, May 10) proposes the manufacture of pure chromium by the following method: Sodium bichromate and zinc sulphate are thoroughly mixed and subjected to a red heat, resulting, besides the development of oxygen, in the formation of zinc chromite and sodium sulphate.

The sodium sulphate is removed by washing with water from which the dissolved salt may be recovered by evaporation and crystallization. The chromite of zinc thus obtained in form of a gray powder, is reduced. It is mixed with powdered carbon, moistened slightly with water containing a little molasses, sugar or other binder, and formed into very solid, compact cakes by heavy hydraulic pressure. These cakes are placed in a suitable crucible or furnace, and are heated until the zinc is thoroughly volatilized, while the carbon combines with the oxygen of the chromite, leaving pure chromium in lumps.

IRON.

W. M. Brown and D. Reynolds (759,590, May 10) suggest the following process of producing iron or steel direct from ores. Granulated iron oxide ore is mixed with sufficient granulated carbon to deoxidize the ore and carbonize the iron to the extent required for the production of the iron or steel desired. This mixture is introduced into revoluble crucibles set in a revoluble shell or furnace. This shell or furnace is heated by the waste products of combustion coming from the melting or fusing furnace. During the revolution of the crucibles the mixture of iron oxide and carbon is thoroughly mixed, but during this process the mixture in the crucibles is protected from the direct action of the products of combustion used in heating the crucibles. After deoxidation and carbonization have taken place, sufficient flux is introduced into the mixture to remove impurities, and the mixture is heated until melting or fusion of the iron results.

T. Rouse (758,853, May 3) proposes to convert iron-sand concentrates into briquettes or lumps as follows. The sand is thoroughly mixed with a solution of about one measure of commercial water-glass in 50 measures of hot water. The quantity of the water-glass solution must be such that when cooled the mixed mass is in a stiff plastic condition, although gritty, so that it can be moulded into briquettes, which are pressed and conveyed to a drying chamber, in which they are hardened in the presence of hot air and steam.

W. W. Hout (759,526, May 10) proposes a welding flux, consisting of calcined borax, iron or steel filings, drillings or cuttings, furnace dross, slag or cinder, and calcined marble dust, in certain proportions.

GENERAL METALLURGICAL APPARATUS.

In order to obtain metals from their ores by chemical or electrochemical means, with a wet process, the ore must undergo previously purely metallurgical treatment, in which the leaching operation is of great importance. Any improvement in mechanical details of this operation helps, of course, the whole process. G. W. Stead (758,713, May 3) describes an apparatus in which at the same time that a liquid is agitated the ore fed in at one end of the receptacle is carried forward progressively and brought into intimate contact with the liquid. For this purpose the pan is provided with a series of agitators or scrapers which extend transversely across the pan with their lower ends adjacent to the bottom. These scrapers are hinged so that they can swing in one direction, and a reciprocatory movement is imparted to the scrapers, so that the ore fed in at the rear end of the pan is advanced progressively through the liquid by the several scrapers in their forward reciprocation and automatically discharged from the latter by the action of the forward scraper.

E. C. Wills (759,791, May 10) patents a furnace for the reduction of ore and for the melting of pig iron and their

metals. His purpose is to provide hearth-like surfaces down which the ore and metal may feed by gravity and to subject the material so fed to the action of a flame from an oil burner independently of or in conjunction with the heat from an ordinary furnace.

R. Baggeley and O. S. Garretson (760,172, May 17) describe a furnace for utilizing the heat contained in molten slag to heat a steam boiler, the molten slag being carried past the heating surface of the boiler by an endless flexible carrier.

F. Siemens (760,263, May 17) describes a regenerative gas furnace with gas producers in close proximity to the furnace chamber; usually the gas is evolved from the producers at a comparatively low temperature, and it is necessary to preheat the gas. Means for this purpose are described.

A. P. Gaines (759,171, May 3) describes a hot-blast apparatus for metallurgical furnaces in which the combustion chamber is entirely separate and independent from the stove or regenerative chamber, so that when the blast is put on the cold-air blast can pass only through the stove and never through the combustion chamber.

G. K. Hamfeldt (759,991, May 17) describes a construction of blast-furnace tops, designed to provide for a good distribution of the stock, especially where a considerable amount of mesaba or other fine ores is used. For this purpose a metal shell is provided which is supported on the stack, and which is of smaller diameter than the internal diameter of the stack; this shell acts as a deflector to propely distribute the stock.

I. R. Davis (758,622, May 3) describes a reversible door for furnaces with details of construction for opening and closing the same.

A. C. Kloman (759,449, May 10) describes a device, which, if a leak occurs in twyers, bosh-plates and cooling boxes, enables one to detect which one of the cooling devices is leaking.

E. E. Taber (759,768, May 10) describes an improved twyer attachment for blacksmith's fords.

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By George P. Scholl, Ph. D.

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

Electric Furnaces and Furnace Products.

Process of Producing Carbide.—W. S. Horry, Niagara Falls, assignor to Union Carbide Co. Patent 757,617, Apirl 19, 1904. Application filed March 29, 1902.

The process applies specially to the production of calcium carbide. The carbide-forming materials, which act as resistance-conductor, are subjected to the action of the current between electrodes so disposed that the current density through the charge increases gradually, till the carbide is formed and brought to a molten condition. A suitable form of furnace for carrying out the process consists of a cylindrical vessel of refractory material, the lower part of which is provided with a number of cylindrical electrodes. The latter are disposed radially, two rows of eight each being shown in the drawing. All these electrodes are connected to one pole of a source of electric current, either direct or alternating. The other pole is connected to a single electrode, situated in the center of the bottom of the furnace, a tap hole for the molten material being arranged close to it. The lines of current flowing thus converge from the various upper electrodes to the single central electrode, thus giving a gradually increasing current density. The water gases pass up through the charge and serve to preheat it, finally escaping near the top of the furnace. Instead of employing a charge containing large pieces of coke, which by their contact with each other afford paths for the current, a mixture of ground coke and lime may be used. In the latter case, however, either an initial conducting path has to be provided, or the radial electrodes must be arranged nearly in the same horizontal plane as the top of the central electrode, the charge being preheated by conduction and radiation, so that it acts as resistance conductor when it reaches the paths of current flow.

Process of Electric Heating.—W. S. Horry, Niagara Falls, asignor to Union Carbide Co. Patent 757,618, April 19, 1904. Application filed April 5, 1902.

The process relates to the heating of a body of conducting material, especially a mixture of a metallic compound and a reducing agent, and more specifically of lime and carbon for the production of calcium carbide. It is based on the use of polyphase currents, preferably with many phases, the idea being to so distribute the paths of the various phases within the charge, which acts a resistance conductor, as to effect an even heating. The furnace used for this purpose, designed for a current of 2000 kw. or more, is a cylindrical vessel near the lower portion of which are arranged two horizontal rows of cylindrical carbon rods, radially disposed, which serve as electrodes. Each row is made up of 24 electrodes, each of which is connected to one terminal of a dynamo or transformer furnishing a current of twelve phases. A tap hole for the molten product is provided at the bottom of the furnace, the process being intended for continuous working. The use of a large number of electrodes is a desirable feature in the process, inasmuch as relatively small electrodes can be used without unduly heating them or their connections. Practically the maximum voltage of the generator is said to be always maintained between one pair of electrodes, the working current thus being always at the maximum furnished by the generator instead of varying from zero to the maximum as with single-phase current. For this reason a saving of about 30 per cent by weight of electrodes is claimed to be effected, as the total cross-section of the electrodes may be that much smaller than would be necessary for a furnace of the same capacity using single-phase current.

Process of Electric Heating.—W. S. Horry, Niagara Falls, assignor to Union Carbide Co. Patent 757,619, April 19, 1904. Application filed April 28, 1902.

This process, like the preceding, depends upon the use of polyphase currents for heating a body of conducting material, especially a mixture of lime and carbon for the production of calcium carbide. It differs from the preceding in so far as one terminal of the various phases of the dynamo is connected to individual carbon electrodes, while the other terminal of each phase leads to a common, centrally situated electrode. The furnace is shown in Fig. 1. The top is closed by a charging device, consisting of bell and hopper, while an outlet tube carries off the waste gases. Two series of electrodes, each containing eight of them, numbered 1 to 8, are introduced through the sides. The armature of the dynamo has eight separate windings, one terminal of each of them being connected to the respective electrodes. The other phase terminals lead to the common electrode 9, which is provided with a tap hole. The process is intended to be continuous.

Method of Electric Heating.—W. S. Horry, Niagara Falls, assignor to Union Carbide Co. Patent 757,620, April 19, 1904. Application filed June 6, 1902.

The method relates principally to the production of calcium carbide and depends upon maintaining a conductive body in a molten state between the electrodes, the body being so disposed that the current density of the current passing through it is variable, and generally a maximum at or near the tapping hole. Thus the body is heated at that place to a relatively high temperature and may be readily withdrawn in a molten condition from the furnace. Such conductive body may be calcium carbide, iron, carbide of iron, or other suitable material. Various forms of apparatus, in which the method may be carried out, are shown in the specification. One construction shows a furnace, the side walls of which converge to a contracted portion in the middle, at which point is located one

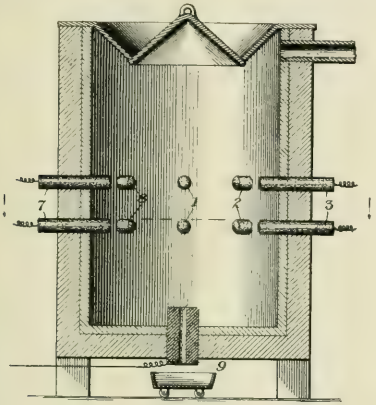


FIG. 1.—CALCIUM CARBIDE FURNACE.

electrode and the tapping hole. Two electrodes of opposite polarity to the central one are located, one at each of the wide ends of the furnace, the bottom of the latter being horizontal. As the cross-section is thus narrowest near the tapping hole, the temperature of the molten material will be the highest, so that it can easily be tapped out. Another construction is shown in which the bottom of the furnace slopes up to a point in the middle, where the tapping hole is situated. The side walls in this case may be straight or also may converge toward the middle. The central electrode may also be omitted, the electrodes at the ends being made of opposite polarity. Several more modifications of the construction are shown in the specification.

Electric Furnace.—W. S. Horry and Edgar F. Price, Niagara Falls, assignors to Union Carbide Co. Patent 757,621, April 19, 1904. Application filed October 11, 1902.

This specification, issued to the above inventors, is substantially worded like the preceding one, issued to one of them, and covers the designs of the furnaces described there, the constructions shown in the drawings being exactly the same.

Electric Heating.—E. F. Price, Niagara Falls, assignor to Union Carbide Co. Patent 757,633, April 19, 1904. Application filed April 5, 1902.

This process also applies primarily to the production of calcium carbide, and the leading idea is the increasing of the density of the electric current through the material under treatment towards the point where it is discharged, the material serving again as resistance conductor. This purpose is sought to be accomplished by supplying additional current to the material at various points on its way to the tapping hole. A furnace construction embodying this idea is shown in Fig. 2. The furnace proper consists of a vertical stack and back of refractory, non-conducting material, and a hearth of refractory conducting material, such as carbon. The latter is connected to one terminal of a source of current. A tubular body 8 of resistance material, preferably in a loose condition, such as lumps of graphitized carbon or coke, is placed into the furnace. The material to be treated is disposed in the form of a column 9. A series of electrodes of opposite polarity to the carbon hearth dip into the top of the resistance conductor. The current density in the lower part of the resistance conductor, and thereby the temperature, is increased

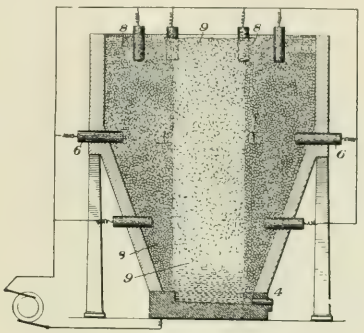


FIG. 2.—CALCIUM CARBIDE FURNACE.

in two ways, in the first place on account of the decrease in cross-section of the resistance conductor, and in the second place by supplying additional current through radial electrodes. As the lower part of the charge column 9 is brought to a sufficient temperature, the calcium carbide is formed and may be drawn off through the tapping hole 4. The furnace is intended to run continuously. Another construction shows the principle outlined above applied to a horizontal furnace.

Electric Resistance Furnace.—E. F. Price, Niagara Falls, assignor to Union Carbide Co. Patent 757,634, April 19, 1904. Application filed April 30, 1903.

The furnace constructions shown in this specification also embody the idea of the superposition of currents in order to increase the density of the current in the resistance conductor, which serves to heat the material to be treated, so as to subject the latter to increasing temperatures on its way to the tapping hole, which is preferably placed adjacent to the region of maximum current density. One of the present construction shows a cylindrical furnace of refractory material, provided with bell and hopper, and outlet for waste gases at the top. It has a lining of carbon, which serves as the resistance conductor. A hearth of carbon, in contact with the carbon lining, is connected to one pole of the electric current. Three hollow metallic rings surround the carbon lining, and are in close contact with it. They are cooled by water or another cooling medium. The first ring is arranged at the top of the furnace, the second one somewhat above the middle, and the third one a little distance above the hearth. All three of them are connected to the other terminal of the current. The density of the current flowing through the carbon lining is thus increased by steps from above downwards, and the temperature of the lining is raised accordingly. A second construction shows a horizontal furnace embodying substantially the same principles. In the third construction the furnace has the form of an inverted cone of refractory material, surrounded by a water-jacket. The hearth is again of carbon, as in the above construction, and connected to one pole of the current. The resistance conductor in this case is formed of a tubular body of carbon, which rests in the middle

of the hearth and extends above the top of the furnace. At its upper end connection is made with the other pole of the current. A second current is superposed upon the first one in the lower half of the tubular resistance conductor, by the introduction into the hollow interior of the latter of another terminal of like polarity to the first. This is kept from contact with the upper portions of the interior of the tube by insulating rings, the contact only taking place at a point in the lower half of the tube. The tapping hole is arranged in the bottom of the furnace. The invention applies to the heating of materials, especially mixtures of a metallic compound and a reducing agent and specifically lime and carbon for the production of calcium carbide.

Process of Electrically Smelting Materials.—Alfred H. Cowles, Cleveland, Ohio. Patent 760,057, May 17, 1904. Application filed October 20, 1903.

The process consists in heating materials, the conductivity of which increases as their temperature rises, in an electric furnace provided with a casing of conductive material. The casing is cooled in order to form a non-conducting layer of solidified material upon it, and thus to prevent shunting of the current through the casing. The furnace consists of an upper cylindrical part, water cooled and carrying a bell and hopper, a middle part of frustio-conical shape, much longer than the upper part and also water cooled, and a lower part, formed by a hearth of carbon, connected to one terminal of the source of current. The upper part is divided from the middle part by a ring of refractory non-conducting material, through which a number of horizontal electrodes, arranged radially are introduced into the furnace. These electrodes are connected to the other terminal of the current. The hearth is also separated from the middle part of the furnace by a layer of refractory insulating material. On starting, after charging the furnace, *e. g.*, with a mixture of ground lime and coke for the production of carbide, the current is carried by one or more narrow cores of broken coke or carbon rods, extending from the upper electrodes to the hearth, until the surrounding portions of the charge are hot enough to serve as resistance conductor.

Process of Making Calcium Carbide.—Alfred H. Cowles, Cleveland, Ohio. Patent 760,312, May 17, 1904. Application filed June 28, 1902.

The process is intended for the continuous production of calcium carbide which is maintained in a molten condition in order to remove it from the furnace through a tapping hole. The charge is used as resistance conductor. The furnace used is illustrated in vertical central section in Fig. 3. It has a solid carbon hearth, surrounded by a layer of fire brick and a sheet-iron casing. A tapping hole is provided and a terminal, which connects the hearth with the source of electric current. An insulating ring of asbestos separates the hearth-casing from a dome-shape, water-jacketed sheet-iron structure, with water inlet and outlet. A pipe for carrying off waste gases and charge openings are also provided. The other electrode is made of carbon and suspended vertically in the furnace. It is intended to produce superheated molten carbide, which means that the carbide has not only been produced and melted by the heat from the resistance conductor but has also been raised to such a temperature that it will run through a tapping hole without requiring an additional supply of heat.

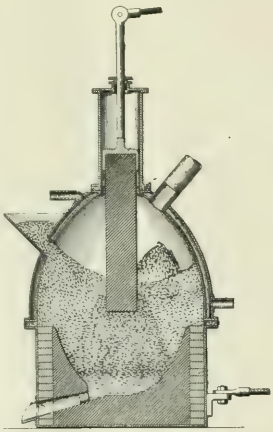


FIG. 3. CALCIUM CARBIDE FURNACE

Electrical Furnace.—R. M. Pelton, Detroit, Mich. Patent 759,909, May 17, 1904. Application filed December 3, 1902.

The furnace is intended for the use of dentists, and its essential part consists of a muffle in the walls of which a coil of heating wire of platinum is located. The outside of the muffle is surrounded by a further heating coil.

Electrolytic Production of Metals and Compounds.

Process of Electrolytically Extracting Copper and Zinc from Ores.—S. Laszezynski, Kielce, Russia. Patent 757,817, April 19, 1904. Application filed October 10, 1902.

The inventor states that in the electrolysis of a solution of sulphate of iron $FeSO_4$, at the cathode the bivalent ferro-ion is metallically deposited, while at the tri-valent ferri-ion $(Fe_2(SO_4)_3)$ and that the iron, before being deposited from the latter compound on the cathode, has to be reduced again; in this manner there is soon set up a state of equilibrium, in which the same quantity of ferro-ions are reduced at the cathode as are produced at the anode. In the present process the detrimental side action at the anode is done away with by wrapping around the insoluble anode a cover or envelope of porous fabric. As soon as the current is turned on, a layer of pure sulphuric acid will form around the anode * * *, so that in a short time the anode is surrounded by diluted sulphuric acid free from iron * * *. In a state of equilibrium, the thickness of the envelop is in inverse proportion to the density of the current, as well as the free ions, also, the not dissociated molecules are diffused, but the latter are inactive and not to be taken into consideration. With a current density equal to one hundred amperes per square millimeter, and a concentration of the ferro-ions equalling half the normal, the thickness of the envelop is about three millimeters. In the strength of these observations, the inventor puts in the following claim: "Process for electrolytically obtaining metals, especially copper and zinc, out of their ores by means of insoluble anodes, consisting in tightly wrapping the insoluble anode in a porous and perfectly permeable envelop of fabric or other suitable material, the thickness of which is in inverse proportion to the applied density of current, for the purpose of preventing anodic oxidation of the cations."

Electrolytic Deposition Apparatus.—W. J. Jory and J. H. Jory, San Francisco. Patent 757,557, April 19, 1904. Application filed April 7, 1903.

The apparatus is intended for the deposition of a variety of metals, among them gold, platinum, silver and quick silver. It consists essentially of a trough-shaped box, of such a capacity that the solution under treatment shall flow through it in a hollow stream, while yet moving at such a rate as to carry off any sands contained in it. The bottom of the trough is formed of plain or corrugated plates of copper, silvered copper or other suitable metal, which constitute one electrode, generally the cathode. A wooden frame secured to the sides of the trough forms a support for a series of shafts, which work in bearings so arranged as to constitute receptacles for mercury, the employment of the latter being made for the purpose of lessening friction and forming an electric conductor. Electrodes of any suitable metal or carbon are fastened to these shafts and dip into the electrolyte. Means are provided by which the level of the apparatus may be changed to regulate the rate of flow as desired. One of the instances of application of the apparatus proposed by the inventor refers to the deposition of precious metals from the flow proceeding from stamp batteries. In this case they propose to introduce a soluble mercuric salt, such as mercuric nitrate or mercuric

chloride, into the batteries, "in such proportions with the metallic contents of the ore as will form an amalgam of such metals in so plastic a form that it may easily be removed from the plates, and yet of such firmness that it will not be carried off in the flow of water and sands." Upon electrolysis during the passage of the solution through the apparatus described above, the mercury is deposited on the cathodes of the apparatus, and according to the claim of the inventors all the precious metals contained in the flow are recovered by amalgamation with the mercury so deposited. Precise data as to voltage, current density, strength of solutions employed, etc., are conspicuous by their absence.

Apparatus for Circulating Liquids in Tanks.—G. E. Dunton, New York. Patent 758,430, April 26, 1904. Application filed September 15, 1903.

The apparatus is specially intended for the continuous circulation and thorough agitation of electrolytic solutions, in which deposition of metals takes place, in order to make the metal deposited at the cathode finer in grain and tougher; to shorten the time of deposition and keep the solutions from becoming heated. The means adopted for carrying out this purpose consist of a pair of centrifugal pumps situated near the top of one of the small ends of the tank and a system of piping which directs the liquid between the anodes and cathodes. The suction pipes of the two pumps reach down nearly to the bottom of the tank, so that the liquid is drawn downward.

Apparatus for Circulating Liquids in Tanks.—G. E. Dunton, New York. Patent 758,513, April 26, 1904. Original application filed September 15, 1903. Divided and refiled November 25, 1903.

The apparatus is adapted to the deposition of the copper shells used in electrotyping. The anodes and cathodes are arranged crosswise in the tank, and the two centrifugal pumps situated as above are each provided with one pipe running along the long side of the tank and furnished with a number of nozzles alternately disposed, so as to discharge the liquid towards the center of the tank between the electrodes and produce a compound motion of the solution.

Process of Obtaining Tin by Electrolysis.—E. Quintaine, Argenteuil, France. Reissued patent 12,214, April 26, 1904. Original, 699,012, April 29, 1902. Application for reissue filed April 20, 1903.

The bath used by the inventor consists of a solution of acid nitrate of tin to which a certain quantity of a salt of ammonia, preferably sulphate of ammonia, is added in order to neutralize it. For producing acid nitrate of tin, he prepares a solution of acid nitrate of tin, to which is added gradually a certain amount of salt of ammonia and a tin chloride, this gradual addition to the solution being continued until precipitation ceases and the bath becomes clear as water. The scrap is placed in a basket of wood or copper wire, and suspended in the bath as anode, while a cathode of lead is recommended. The tension of the current is given as ordinarily 1.7 volts, which should not be higher, and the current density as between 20 and 25 amperes per square meter.

Titanous Compound and Process of Making Same.—H. Spence, Manchester, England. Patent 758,710, May 3, 1904. Application filed September 11, 1902.

The invention relates to the manufacture of a new titanous sodium sulphate compound for use as reducing agent for various purposes, especially in the textile industry. The inventor has found that when a solution of the double basic compound of titanium sulphate and sodium sulphate, the preparation of which was described in his patent 670,819, of March 26, 1901, with the addition of sulphuric acid, is subjected to electrolysis, the resulting reduced solution contains a new double compound of titanous sulphate (sesquisulphate) and sodium sulphate of the composition (after drying in vacuo) Na_2SO_4 $Ti(SO_4)_3$ $5H_2O$. The solution is prepared by dissolving 100 parts by weight of the double basic compound of titanium sulphate and sodium sulphate in water, with the addition of 23 parts by weight of sulphuric acid containing 66 per cent of SO_3. The amount of water employed is such that the strength of the solution shall, after reduction, be of about 1.3 spec. gr. It may also be made by dissolving 100 parts of titanium hydrate containing about 20 per cent of TiO_2 in about 53 parts of sulphuric acid containing 66 per cent SO_3, diluting it to 1.3 spec. gr., and after subjecting it to electrolysis adding to the resulting reduced solution a little more than one molecule of sodium sulphate for every molecule of Ti_2O_3 present. The electrolytic reduction may be carried out in a lead-lined vessel, divided into two compartments by a diaphragm, the anode being of lead and the cathode of carbon, or also of lead, a solution of sulphuric acid in water being placed in the anode compartment. A current density of about 10 to 15 amperes per square foot of cathode surface, with about 4 volts pressure, is stated to give good results, electrolysis being carried out at a temperature between 15° and 30° C. The resulting titanous liquor is evaporated to about 1.45 spec. gr., and the mother liquor separated from the lilac-colored crystals which should be kept dry, in which condition they are said to be very stable. The new compound is said to be a powerful reducing agent and also very suitable for the production of other titanium compounds, *f. i.*, titanous acetate by double decomposition with sodium acetate. (See the note on page 250 on titanium trichloride.)

Electrolytic Apparatus.—H. S. Blackmore, Mount Vernon, N. Y. Patent 759,798, May 10, 1904. Application filed July 22, 1903.

The apparatus is especially intended for the electrolysis of an equeous solution of chloride of sodium, with a mercury cathode. It comprises a vessel for electrolysis and another one where the amalgam is discharged, together with several other vessels intended to regulate the flow of mercury. The electrolytic vessel contains a mercury cathode and a row of anodes suspended from the cover, a receptacle for solid sodium chloride being arranged on two sides. These receptacles are in communication with the electrolyte which they maintain in a saturated condition. The electrolytic cell communicates with two cylindrical vessels, which, in their turn, are connected to the amalgam discharging vessel. The latter is of rectangular shape, and the amalgam is introduced at one corner, whence it flows through several compartments formed by baffle plates alternately leaving passages at opposite ends, and issues at the corner diagonally across from where it entered. Electrodes of carbon or other relatively electronegative material may be employed for increasing the rate of oxidation of the sodium. The water in the discharging vessel flows in the opposite direction from the mercury. The mercury, after discharge, flows into a cylindrical vessel provided with a valve outlet controlled by a float, from which a pipe leads it into a collecting vessel, whence it is pumped back into the main reservoir. From the latter it goes to a cylindrical vessel with a ball float, which serves to maintain a column of mercury at uniform level in the electrolytic cell, and then enters the latter to be charged and discharged again as above. The movement of the mercury and amalgam through the various vessels, is said to be effected solely by the differences of level of the various bodies of mercury and amalgam, and these differences to be maintained by suitable predetermined adjustment of float-feed and float-controlled outlet and of the height of the connecting pipes.

Electrolytic Apparatus.—H. S. Blackmore, Mount Vernon, N. Y. Patent 759,799, May 10, 1904. Original application filed June 22, 1903. Divided and refiled February 23, 1904.

The apparatus is primarily intended for fused bath electrolysis with a view to the production of a lead sodium alloy and the recovery of the sodium therefrom. It is illustrated in Fig. 4. The electrolytic vessel proper 1 is made of iron heated by a burner 5 and connected with the negative terminal of the current. A cover supports an anode chamber, 14.

A disc 21 of iron wire gauze carries a diaphragm 22 of greater spec. gr. than the molten electrolyte, and lesser spec. gr. than the molten lead cathode. Magnetite broken into angular fragments, which pass through a 50-mesh has been found especially suitable. The anode is made of graphite while a cathode of molten lead fills the lower part of the outer iron vessel. The lead sodium alloy produced by electrolysis is said to be continuously displaced from the surface of the cathode beneath the diaphragm and to rise to the surface of the cathode around the anode chamber. Provision is made to remove the sodium from the alloy in the following manner. An annular pipe 29 with two rows of outwardly and downwardly opening perfora-

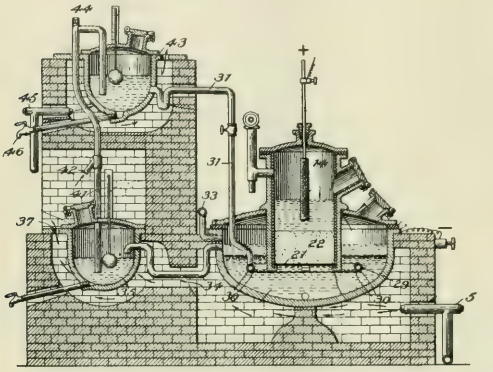


FIG. 4.—PRODUCTION OF SODIUM BY ELECTROLYSIS OF FUSED SALT.

tions is located in the molten lead cathode, through which a stream of molten sodium hydrate is introduced through pipe 31 from vessel 43. The molten sodium hydrate is said to be reduced by the sodium in the alloy to sodium oxide, with evolution of hydrogen, which latter escapes through pipe 33. The sodium oxide is said to float on the surface in a molten condition, and to be drawn off by an inverted syphon 34 into vessel 35. A layer of loose granular material, which may be small angular fragments of iron magnetite or ferrosilicon, is introduced beneath the surface of the cathode and kept submerged by a horizontal ring of wire gauze. This layer is stated to break up and distribute the streams of sodium hydrate rising from pipe 29 and bring them into intimate contact with the sodium in the alloy, the oxidation being facilitated by the innumerable local couples due to the contact of the sodium and the relatively negative particles of iron, etc. The sodium oxide in vessel 35 is kept molten by the waste gases escaping by passing along 34 to 35 and 37. The sodium oxide is preferably constantly converted into sodium hydrate, and for this purpose a pipe 41 leads from vessel 35 to vessel 43, past a steam injector 42, which serves both to introduce the water necessary for hydration and to carry the material upwards. The vessel 43 is also provided with a float level indicator and outlet 46, and it is heated by burner 45. The amount of sodium hydrate which is required to oxidize the sodium in the sodium lead alloy, continually passes from vessel 43 through a trapped outlet into the pipe 31.

Process of Manufacturing Peroxides.—F. Hinz, Berlin, Germany. Patent 759,887, May 17, 1904. Application filed November 23, 1903.

The process relates to the electrolytic production of magnesium peroxide and zinc peroxide in a vessel separated into two compartments by a porous diaphragm, with an anode of platinum or carbon, and a cathode of platinum or tin. The anodic electrolyte in the production of magnesium peroxide consists of a solution containing about 200 grams of magnesium chloride per liter while the cathode compartment is charged with a solution of hydrogen peroxide, containing about the same quantity of magnesium chloride, after any free acid has been neutralized with magnesium oxide or hydroxide. The voltage at the terminals is stated as about six to seven volts, the current density is not given. Magnesium peroxide in the form of a white powder is said to be deposited on the cathode, "when the current is sufficiently strong." It drops down into the cathode compartment and is collected, washed and dried at a moderate heat. The production of zinc peroxide takes place in a similar manner, but electrolysis is carried out at a pressure of 2.5 to 3 volts.

Apparatus for the Electrolytic Refining of Metals.—A. Schwarz, New York. Patent 760,023, May 17, 1904. Application filed November 22, 1902, renewed November 20, 1903.

The apparatus differs from the usual type in the arrangement of the electrodes. Instead of employing electrodes which are parallel to each other the inventor uses a large number of small cathode plates, suspended from a support which rests upon the top of the electrolytic tank in such a manner that their edges are turned towards the anode. The latter may be of the usual form, or it may be provided with projecting ribs, in order to give it also an increased surface. The inventor states that under conditions of practical copper refining he has found it practical to employ as many as forty-eight cathode plates, each twelve inches long and one inch wide, which at 24 square inches depositing surface per plate would give a total of 1152 square inches as compared with a single cathode plate of a total depositing surface of 288 square inches as heretofore employed with a corresponding section of the tank. To prevent the deposition of metal on the edge of the cathodes near the anode, the edge may be covered with some insulating material.

Storage Batteries.

Secondary Battery.—L. H. Flanders, Wilkinsburg, Pa., assignor to Westinghouse Machine Co. Patent 757,446, April 19, 1904. Application filed July 10, 1903.

The invention relates to means of supporting and separating the electrodes of storage batteries. The battery jar has a supporting block in the bottom at each end, upon which rest corrugated separator plates, preferably formed of porous earthenware. The edges of these separators are considerably thicker than the corrugated body portion, and fit tightly against each other, so as to completely enclose the electrodes, which rest on their upper edges by means of lugs. It is claimed that a battery of this kind may be conveniently and cheaply assembled, that the formation of short circuits is prevented, and that the electrodes may be readily removed without disturbing the separators.

Process of Making Storage Battery Plates.—Joseph Bijur, New York. Patent 757,718, April 19, 1904. Application filed February 10, 1903.

The plate consists of a number of grilles, which are assembled and united together by means of molten lead. In order that the grilles may not be clogged up by the molten metal, their interstices are filled with a material which can afterwards be dissolved by a suitable solvent. Such filling materials are soda ash or pearl ash or other bodies, which, under the conditions of the process, remain infusible, incombustible, non-delinquescent, beneficial or at least harmless, chemically, non-gas-giving and cohesive after drying from a paste made with a non-solvent, *f. i.*, alcohol, and soluble by an agent which does not injure the plate.

Storage Battery.—A. V. Meserole, New York. Patent 757,943, April 19, 1904. Application filed July 13, 1903.

The battery shows a containing vessel in which the positive electrode is supported from bars running across the top of the vessel, while the negative electrode rests on the bottom. The positive electrode is made up of a number of tablets or wafers of active material, which have a hole in their center and are

piled up, one on top of the other, on rods depending from the above bars. The negative electrode consists of a tray of bronze provided with partitions which form a series of troughs, in each of which a slab of active material is placed. The tablets of which the positive electrode is made up are composed of peroxide of lead, combined with about 1 per cent of chemically precipitated sulphur and about the same portion of a "chemical precipitate of silver compound—such, for example, as an oxide." These materials are mixed preferably with water containing an acid sulphate, the nature of which is not disclosed. The slabs of active material for the negative electrode are composed of lead, zinc, mercury and copper, combined in any convenient manner, but preferably in the form of chemically precipitated metal pressed into tablets. The quantity of zinc and mercury, by weight, should be about double that of the lead and copper. The electrolyte may be any liquid suitable for storage batteries, but with the above materials dilute sulphuric acid is preferably employed.

Storage Battery.—J. T. Niblett, Greenwich, England. Patent 759,007, May 3, 1904. Application filed February 5, 1903.

The cell consists of an outer vessel of lead, preferably forming the negative conductor, and a porous vessel placed inside of it. The porous cell contains a central conductor which is embedded in a packing of granular material, which fills the whole interior of the porous cell. The space outside of the porous vessel is also filled with granular material, constituting the negative element. The inventor finds it advantageous to use a mixture of two kinds of granules, one kind being formed of granulated lead or lead alloy, and the other of molded pellets of lead oxide, mixed with about 2 per cent of infusorial earth. The electrolyte fills the spaces between the granules.

Storage Battery.—W. J. Redmond, Cleveland, Ohio. Patent 758,692, May 3, 1904. Application filed September 29, 1902.

The plate is formed with a series of filaments or pin-like projections for the purpose of retaining the active material, about 250 filaments to the square inch having been found to give satisfactory results. The pins may be formed by inserting a suitable tool at a slight angle into the body of the plate, so as to shave or cut a thin filament from its face, at the same time leaving one end attached to the plate, and then turning the filament up or out, so that it stands at approximately right angles to the body of the plate. Strengthening ribs may be provided along the core of the plate by decreasing at suitable points the amount which the tool is allowed to penetrate into the plate.

Storage Battery.—V. G. Apple, Dayton, Ohio. Patent 759,058, May 3, 1904. Application filed June 5, 1901.

The battery is designed for use on automobiles. The inventor claims: "In a storage battery, a battery-containing conducting case, divided into two compartments, the inside surfaces of each compartment electrochemically active, a series of liquid-tight conducting cases, one within the other, and insulated one from the other, their respective interior and exterior surfaces electrochemically active, within each compartment, and a central element within the inner case of each compartment constituting the electrodes."

Method of Accumulating and Using Electrical Energy.—A. G. Betts, Troy, N. Y. Patent 759,065, May 3, 1904. Application filed August 17, 1903.

The inventor has found on passing an electric current of moderate strength through an electrolyte composed of a strong solution of lead fluosilicate containing some free acid, or of a somewhat acid solution of fluosilicates of lead and another metal as copper, with graphite electrodes, that peroxide of lead is deposited on the anode in a dense adherent and well-conducting form, while metallic lead or the other metal is deposited on the cathode, free fluosilicic acid remaining in solution. When the battery thus formed is allowed to discharge, the lead or other metal and the peroxide of lead recombine with the fluosilicic acid, thus restoring the original conditions. For charging the battery a current density of 10 to 20 amperes per square foot of negative electrode surface is suitable, the potential required being about 2 volts. A concentrated solution of lead fluosilicate at ordinary summer temperature contains about 900 grams of lead and 35 grams of about 2.38 spec. gr. fluosilicic acid per liter, about 20 pounds of this solution representing a storage capacity of 1 electrical hp. hour. It is stated that the lead during the discharge shows a tendency to become soft, so that at the end some of it may not be firmly attached to the electrode. If the charging current is reversed, the loosely attached pieces may be completely removed and a better adherence obtained for the deposit. The electrodes are therefore both made of insoluble material, so as to allow of a reversal of the charging current. A small amount of gas is given off from the positive electrode until the graphite has been evenly coated with peroxide of lead. On account of this a small amount of lead or other metal remains undissolved on the negative electrode after complete discharge, which amount, though small, would gradually accumulate. This is corrected by the introduction of air, which also helps in increasing the circulation of the electrolyte. It is stated that for certain purposes a solution of metallic salts of various acids, including fluorine acids, such as fluoboric, fluotitanic, fluosilicic acids and others, while carbon, platinum or other insoluble electrodes may be used.

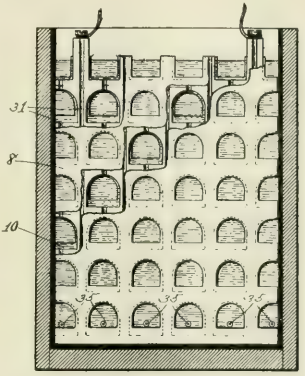


FIG. 5.—STORAGE BATTERY.

Electric Storage Battery.—A. G. Betts, Troy, N. Y. Patent 759,066, May 3, 1904. Application filed August 17, 1903.

The battery is illustrated in Fig. 5 and has been constructed with an idea to maintain any electro-deposited material which has become separated, in contact with the electrodes. The wooden cell is provided with a rubber lining. Each electrode is formed of a grating of artificial graphite with numerous openings to permit the free circulation of the electrolyte. Interposed between the electrodes are plates or mats of insulating material, such as rubber, which are provided with openings corresponding to those in the electrodes, but of smaller area. They thus form a pocket in the bottom of each electrode aperture, which catches electrodeposited material that has fallen off and hold it in contact with the electrode. Air nozzles with apertures 35 serve for the introduction of air.

Storage Battery Electrode.—C. J. Reed, Philadelphia. Patent 759,550, May 10, 1904. Application filed January 16, 1901.

The plate is of the Planté type and composed of a number of panels of thin metal, the exposed surfaces of which are angularly disposed with reference to the plane of the plate. The plate is preferably formed by passing molten lead between corrugated rolls of suitable surface configuration and dimensions, and then subjecting the plate thus produced to lateral edgewise compression for the purpose of reducing the corrugation-grooves to the smallest practicable width.

Electric Accumulator.—R. Fortun and E. Semprun, Madrid, Spain. Patent 759,431, May 10, 1904. Application filed September 30, 1901.

The invention relates to a process of manufacturing a so-called new active material for accumulators. The material is produced as follows: A sheet of lead and a lead tube are the respective electrodes in an electrolyte, and are subjected to a current, "the intensity of which at a pressure of 110 volts should not exceed 0.6 amperes for each 1,000 cubic centimeters of the liquid." The liquid is composed of "a solution of oxide of lead (PbO), chemically pure in a potassium hydroxide lixiviation at 32 per cent the oxide dissolved by saturation 700 parts, rock candy 200 parts, neutral potassium tartrate 100 parts." "As the current passes, a brown substance is slowly deposited on the lower sheet of lead, which substance when properly dried up and subjected to an electrolytic analysis during a sufficient time in order that in acting as a positive pole electrode within a platinum crucible its weight may not be further increased." One hundred grams of this substance are claimed to be capable of fixing 369 grams of oxygen. Then follows the announcement that this mysterious dynamatized substance "is not susceptible of being preserved and of reacting as already stated, except when immersed in an electrolytic liquid, such as a solution of seventeen parts of nitrate of lead in 100 of water acidulated with pure nitric acid until it registers 20° Bé."

Galvanic Elements.

Gas Battery.—J. H. Reid, Newark, N. J. Patent 757,637, April 19.

The battery described in the specification is illustrated in cross-section in the adjoining Fig. 6. A metallic pot preferably rectangular, has inside a number of longitudinal partitions 2, 2. A metallic extension 3 of the pot is insulated from the latter by insulating strips. The extension 3 has longitudinal slits forming a grid, the bars 7 of which are

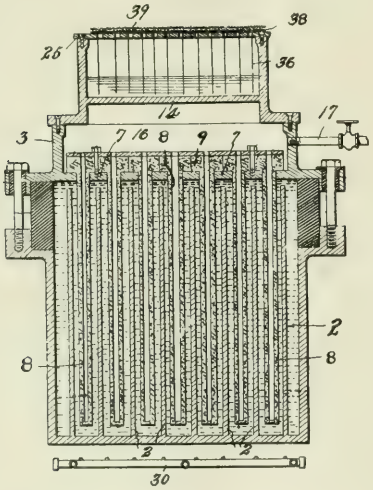


FIG. 6.—GAS CELL.

above the partitions 2; the electrolyte also extends above the latter partitions and is preferably composed of molten sodium or potassium hydrate at a temperature approximating 400° F. Between the bars 7 are inserted electrodes consisting of porous carbons, thin enough to pass between the bars, but having heads 9 which rest on the latter. The material of the electrodes is pervious to gases, but impervious to the electrolyte. Holes 8 are bored into the electrodes nearly to the bottom. An inclined flooring 14 of metal covers the gas chamber 16, which extends above all electrodes. A gas supply pipe 17 serves to introduce a combustible gas. The cover 25 of the cell is perforated, the follower plate having a number of fine holes bored close together. Wires 36 are suspended from the cover extending nearly down to cover 14. Above plate 25 is a layer of wire gauze 38 and finer gauze 39. One terminal of the current is connected to the electrodes 8, while the other is connected to the containing vessel. The electrolyte is heated by a suitable heater 30. The combustible gas passes into the porous electrodes and through them, and air is being forced into the electrolyte near one end. The electrolyte bubbles and froths over the flooring 14, the bubbles being broken by the wires 36 and the liquid returns to the main vessel, flowing down the inclined floor. Carbonic acid and other waste gases, released from the bubbles, pass off through the cover.

Battery.—J. Noble and E. L. Anderson, St. Louis, Missouri. Patent 759,740, May 10, 1904. Application filed June 1, 1903.

The battery consists of a lower part which contains two ring-shaped electrodes the anode being of aluminium and the cathode of carbon. The electrolyte is dilute nitric acid. The upper part of the cell is filled with a mass of carbon or coke, which is kept moistened, and has the purpose of condensing the gases given off in the operation of the cell. The operation of the cell is believed to be as follows: When the circuit is closed the current passes from the aluminium anode to the carbon cathode, decomposes water, setting free oxygen and hydrogen. The hydrogen is oxidized to water while nitrogen peroxide is formed. This gas, as the cell is maintained at a temperature of 150° F. or greater, oxidizes the carbon cathode, forming carbonic acid and nitrogen oxide. The latter unites with the oxygen given off at the anode, and passing into the condenser is there reduced to nitric acid and returns as such to the cell. The inventors, however, do not make any positive assertion on theories as to the chemical or electrochemical reaction which takes place in the operation of the cell.

Miscellaneous.

Apparatus for Electroplating Sound Records.—G. K. Cheney, New York. Patent 758,352, April 26, 1904. Application filed June 6, 1903.

The invention relates to means by which sound-record discs, made of soft wax are suspended in an electroplating tank and connected with the source of current.

Method of Generating Gaseous Mediums from Air.—J. N. Alsop, Owensboro, Ky. Patent 758,883, May 3, 1904. Application filed May 29, 1903.

The method consists essentially in the formation of an arc by allowing two electrodes, the lower one of which is stationary, while the upper one is movable, to come into contact and then drawing them apart. The electrodes are disposed in tubes, which are connected to an exhaust pump, the tubes being preferably arranged in sets of two or more, and operated alternately, the arc in one set being produced when the one in the other is extinguished. Mechanical means for bringing about this alternation are shown in the specification. It is claimed that a current of very low potential can be employed, as the electrodes are actually brought into contact. In order to meet the increased resistance as the electrodes are drawn further apart, a coil of high self-induction is introduced into the circuit. The inventor states that in practice he has used a dynamo designed to give 5 amperes at 500 volts, and an induction coil of a 100 ohms, and with the above apparatus he has produced a gaseous medium of a bleaching and purifying character with the voltage across the arc varying from 150 to 900 and the current in the arc circuit varying from 20 to 0.1 ampere. The gaseous medium produced is applied for whitening and purifying cereals.

Apparatus for Generating Gaseous Mediums from Air.—J. N. Alsop, Owensboro, Ky. Patent 758,884, May 3, 1904. Application filed May 29, 1903.

This specification covers the apparatus described in the preceding one by the same inventor.

Apparatus for the Treatment of Gases.—H. Pauling, Gelsenkirchen, Germany. Patent 758,775, May 3, 1904. Application filed November 20, 1903.

The invention relates to the treatment of gases, vapors and the like by electric spark discharges. The apparatus consists essentially of a funnel-shaped vessel, the funnel tube of which is connected with an air pump. A revolving shaft enters for some distance into the mouth of the funnel-shaped vessel, which is provided with an insulating cap at its ends. The cap is only pierced at one point by a laterally extending projection on the shaft. The latter is connected with one pole of an induction coil, while the funnel-shaped vessel is connected to the other pole. As the shaft revolves, a circular spark disc, caused by the continuous displacement of the above projection, will be formed, through which sparks the atmospheric air has to pass, as it is drawn through the apparatus by the air pump mentioned above. An alternative form of the apparatus shows a hollow shaft and hollow projection, through which the entering air is drawn, which air consequently has to pass through the active zone, and is for some time subjected to the effect of the sparks.

Purifying Apparatus.—P. J. Boucher, Cleveland, Ohio. Patent 760,302, May 17, 1904. Application filed March 28, 1903.

The apparatus is intended for the purification of water or other liquids by electrolysis and consists essentially of a cylindrical receptacle with insulating head. A number of aluminium plates alternately connected to their respective electrode, are arranged longitudinally in the above vessel. A mechanical construction is shown which provides for automatically reversing the current at predetermined times, and for insuring the current being turned on or off, whenever the liquid is turned on or off. Means are also shown for automatically relieving the pressure of the gases which accumulate in the upper part of the electrolyzer during electrolysis.

SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.

INDUSTRIAL ELECTROCHEMISTRY.

Gravity Process for Electrolysis of Sodium Chloride.—The essential requirement of producing sodium hydroxide and chlorine by electrolysis of sodium chloride is to keep the anodic and cathodic products of electrolysis separated from each other. Various methods are in actual use to accomplish this result such as the use of a diaphragm cell or the use of a mercury cathode, both of which are worked on a large scale. The latest process which has made its appearance in the industry is the gravity process (Glocken process, as the Germans call it, on account of the form of the glocke, *i. e.*, bell, which surrounds the anode). This process has been worked since 1895 in Aussig in Austria, and has later been introduced in three plants in Germany. An interesting account of an investigation of this process is given by O. STEINER in the *Zeit. f. Elektrochemie* of May 6. The principle of the method is shown in Fig. 1. The anode is shown in the center and is surrounded by the glocke (bell). There are two openings in the top of the bell, one for introducing the chloride the other for carrying off the chlorine gas. The cathode is placed outside of the bell, and an overflow is provided by which the hydroxide formed at the cathode may flow off. The hydroxide mixed with chloride solution is in the outside cathodic compartment and in the lower part of the bell. Above this lower part, the bell contains a chloride solution with chlorine dissolved in it. The latter solution has a lower specific gravity than the hydroxide solution, so that it floats upon the latter. There is no diaphragm to keep both solutions separate from each other, and the separation is wholly accomplished by making use of the specific gravity. Between both solutions there is a layer of neutral solution and

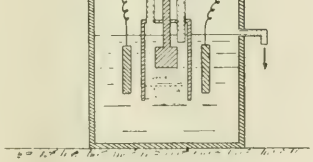


FIG. 1.—GRAVITY CELL.

the main requirement for continuous operation is that this layer of neutral solution is maintained at its place during operation. It acts like a liquid diaphragm. When hydroxide is formed at the cathode, OH ions will, of course, begin to precipitate in the transmission of the current and will travel from the cathode to the anode. It is most essential that these OH ions should not come near the anode, since this would result in the formation of hypochlorite. The main cause which prevents them from passing through the neutral layer of solution which separates the anolyte from the catholyte, is the difference between the chloride concentrations at the anode and at the cathode. The author discusses this point at some length. He shows that the separating neutral layer always remains at the same place if the degree of alkali in the catholyte going off through the overflow is maintained constant by keeping the current constant and the rate of supply of chloride to the anode compartment also constant. If the current is increased or the rate of supply to the anode compartment is diminished, the contents of hydroxide in the catholyte increases and the neutral separating layer will raise upwards. In actual practice there should be a considerable distance between the anode and the lower rim of the bell, so that the neutral layer is at some distance from the anode, so that no ClO ions can reach the latter. The supply of fresh chloride should be evenly distributed over the whole anode surface. The author gives the results of a long series of experiments in which he first determined the efficiency which can be obtained. He found that in continuous operation an ampere-hour efficiency of 85 to 94 per cent may be obtained, yielding an hydroxide containing 120 to 130 grams KOH per liter, and 97 to 100 per cent pure chlorine gas, with a current density of 2 to 4 amperes per square decimeter of horizontal cross-section of the bell, with a voltage of 3.7 to 4.2 between the electrodes. The ampere-hour efficiency is nearly independent of the contents of hydroxide in the final solution, at least up to the maximum of 130 grams KOH per liter. The supply of fresh chloride should be uniformly distributed over the whole horizontal cross-section of the bell. If a colorless solution is wanted with the use of artificial carbon electrodes (such as made by Lessing), simultaneous sand filtration is necessary, since the carbon disintegrates. Without sand filtration the brown color may be removed by oxidizing agents; for in-

stance, by means of chlorine gas. The distance of the neutral separating ozone from the lower rim of the bell is the greater, the smaller the contents of chloride in the supply of fresh solution and the smaller the current density per horizontal bell cross-section and the higher concentration of hydroxide in the final cathodic solution. The vertical distance of the lower surface of the anode from the lower rim of the bell is of great importance for the practical operation of the method. It should be such that the neutral solution is at least one centimeter below the anode. The above distance must therefore be the greater the higher the hydroxide concentration of

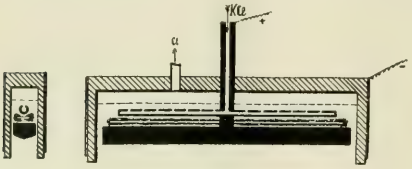


FIG. 2.—BELL FOR COMMERCIAL GRAVITY CELL.

the final solution and the lower the chloride concentration of the fresh supply of solution, and the lower the current density. For a 27.5 per cent KCl solution which is well distributed over the anode surface, in order to get a final solution containing 130 grams KOH per liter with a current density of 2 to 4 amperes per square decimeter of horizontal cross-section of the bell, the distance of the lower surface of the anode from the lower rim of the bell should be at least 4 to 5 centimeters. If these conditions are fulfilled, Acheson graphite is very suitable as anode material, since with a current density of 2 amperes per square decimeter, it does not disintegrate, the supply of solution containing at least 270 grams KCl per liter and being uniformly distributed over the whole anode surface and the hydroxide concentration of the final solution being not more than 125 grams KOH per liter. In an experiment with a current density even as high as 4 amperes per square decimeter, the author did not find a disintegration of Acheson graphite. For the technical operation the bells must be very narrow (about 10 cm.), since with greater breadth, the anode surface cannot be well utilized. Their length should be not more than consistent with a good distribution of the fresh solution over the anode surface. A bell, of the form shown in Fig. 2, 7 centimeters broad and 17 centimeters long could be used at 4.2 volts and 20 amperes, with a current density of 4 amperes per square decimeter. For a daily production of 5,000 kilograms solid caustic and 9,000 kilograms bleaching powder there would be required 5,000 such bells. With a current density of 2 amperes, 10,000 bells are required for the same output. It is estimated that the number of bells at present in use is 45,000.

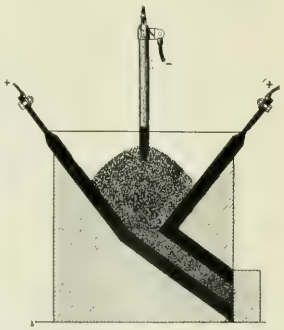


FIG. 3.—GRAPHITE FURNACE.

Manufacture of Artificial Graphite from Charcoal.—In *Metallurgie* of April 22, J. Weckbecker describes some laboratory experiments on the preparation of artificial graphite from charcoal. If carbides are heated beyond their dissociation temperature, the liberated carbon is obtained in the form of graphite. For technical applications it is important to choose a carbide which has a low dissociation temperature, while the other liberated element has a low temperature of vaporization, so that the graphite is obtained in pure form. As substances forming carbides he used aluminium oxide, clay and magnesia. In his first experiments he mixed powdered charcoal with varying quantities of aluminium oxide or magnesia and pressed this mixture to which tar had been added, to rods of 10 mm. diameter. To remove the tar, these rods were packed into a crucible, covered with charcoal and placed in a gas furnace. The rods thus prepared were used as resistances between two carbon poles, in order to bring them to different temperatures. With an addition of Al_2O_3, at a temperature of about 2,000° C. he obtained the best results 11 the amount of aluminium oxide was about 30 per cent. With lower amounts of aluminium oxide equally good results could be obtained if the temperature was increased. With the use of clay, instead of Al_2O_3, the formation of graphite was nearly as good, although there were small crystals of carborundum within the graphite. Experiments with magnesia, however, did not give satisfactory results. The reason is that magnesium carbide decomposes at red heat. The graphite formation with rods consisting of 20 per cent of magnesia and 80 per cent of charcoal was the same as with rods of charcoal without the addition of any magnesia. In other words magnesia gives no graphite, because at the reduction temperature of its oxide no carbide is obtained. The author thinks this is a proof that the carbide formation must precede the graphite formation. He describes various forms of furnaces which he has devised for continuous manufacture of graphite. He had some difficulty to find a satisfactory furnace lining; in some cases he used carborundum bricks. One of his furnaces is shown in Fig. 3; one electrode is formed by the carbon walls of the furnace, while the other electrode is perpendicularly suspended at the top.

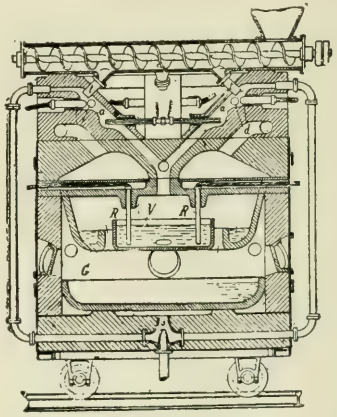


FIG. 4.—GLASS FURNACE.

Electric Glass Furnace.—The *Electrical Engineer*, of London, April 15, states that electrical furnaces are giving good results at the large glass factories at Matri in Tyrol, and at Plettenburg in Westphalia. Fig. 4 shows a furnace which is stated to have given satisfactory results. The raw material enters the top of the furnace through the tubes *tt*, and is then conducted in front of the arcs *aa*. The heat of the arc fuses the material which then drops into the receptacle V, where a current is passed through the material by means of the electrodes RR. The furnace is thus a combination of an arc and a resistance furnace. From V the molten glass descends into a crucible G, which is heated by an upward flame, formed by the gases which are developed during the fusion of the material. These gases are conducted to the flame through the lateral tubes shown in the illustration. In a later type of furnace the raw material, before having been exposed to the heat of the arc, is made into a paste with water. It is then pressed and dried, and finally it passes, in the shape of a ribbon, through the arcs between a number of electrodes, out of which it emerges completely fused. The heating is chiefly

done by radiation and care is taken to prevent impurities from the carbon entering the molten glass.

The Thermo-Magnetic Selector.—An interesting application of magnetism to metallurgical purposes is the recent device of Sauveur and Whiting (*Proc. American Society for Testing Materials*, Vol. III., 1903.) If steel is rolled and finished too hot, it crystallizes while cooling and deteriorates in quality. If the finishing temperature is below 700° C., no crystallization ensues. But, this temperature is that at which iron becomes magnetic on cooling. In order, therefore, to select the steel rolled down to the proper temperature, a powerful electro-magnet acts upon the steel as it comes through the last pass of the rolls. If it is below 700° it is attracted downward, its end passes under a guide, and it passes off as an acceptable piece. If its temperature is above 700°, it is not attracted, and its end passes over the guide and the piece is thus rejected until rolled over at the proper temperature. It is an interesting application of scientific principles.

Cathode Copper.—An editorial is published in the May issue of *Metal Industry* claiming that cathode copper received from electrolytic refineries often greatly lacks in uniformity; the reason is thought to be that the electrolytic refining process is exceedingly delicate and unless constant vigilance is maintained concerning several points, the quality of the cathode will suffer. The writer advocates the use of ingot copper in preference to cathode copper.

Electric Furnace Processes.—In *Cassier's Magazine* of May, J. WRIGHT gives a description of various electric furnace processes which have either been proposed or have been introduced into practice. The article is fully illustrated.

THEORETICAL AND EXPERIMENTAL.

Electrolysis of Sulphites.—The *Zeit. f. Elektrochemie* of April 22, contains a long paper by A. FRIESSNER giving the results of a laboratory investigation. During the electrolysis of neutral and alkaline sulphites of potassium or sodium, there is no development of oxygen at the anode for an average current density, but the sulphite is oxidized to sulphate. Under suitable conditions dithionate may be formed according to the equation

$$2SO_3'' + 2OH' + 2H' + 2F = S_2O_6'' + 2H_2O$$

where F means a positive charge. In an acidulated solution dithionate is never obtained, but sulphate is formed exclusively. If bisulphite is electrolyzed without a diaphragm, sulphate is formed at the anode and hydrosulphite at the cathode, and there is also formed thiosulphate, probably by cahodic reaction. The electrolytic formation of dithionate occurs at ordinary temperature at an anodic potential which is higher than that required for the formation of sulphate. This potential required for the formation of dithionate can be best obained by a previous anodic polarization of platinized anodes in sodium hydroxide. The increase of temperature favors the formation of dithionate. The electrochemical formation of dithionate may be compared with that of persulphates and percarbonates.

Electrolysis of Water with Alternating Currents.—R. G. VAN NAME and L. GRAEFENBERG have investigated the formation of oxygen and hydrogen gases by electrolysis of water with alternating currents; their results are published in an article in the *Zeit. f. Elektrochemie* of April 29. They measured the output of the gases and the voltage required for platinum and gold electrodes in sulphuric acid, and for silver, nickel or copper electrodes in potassium hydroxide. The frequency was kept constant at 55 periods per second, while the current density was varied. The highest efficiency which was observed was only about one-half that which can be obtained with direct current. Moreover, on account of disintegration of the electrodes, the maximum obtainable efficiency could be maintained only for a limited time. Various materials were examined concerning their suitability for electrodes with alternating currents, but it seems that a substance which is a good conductor and which does not integrate at a high frequency does not exist.

Calomel Electrode.—A paper published in the *Zeit. f. Elektrochemie* of April 29, gives the results of an investigation by H. LEY and C. HEIMBUCHER on the concentration of mercury ions in the calomel electrode and on the solubility of calomel. For the Hg_2'' ionic concentration in a 0.1 normal electrode and in the 1 normal electrode they find the values, 2.0×10^{-18} and 3.5×10^{-18}, respectively.

Concentration of H' ions.—The *Zeit. f. Elektrochemie* of May 13, contains a paper by E. SALM on the determination of the concentration of H' ions in a solution with the aid of indicators; with some polemical remarks concerning an investigation of Sallesky. For hydrogen electrodes he used platinum and palladium sheets and found that palladinizing the electrodes was more useful than platinizing, since with the former a better constancy is obtained, and the equilibrium is reached more quickly. To cover the electrode with palladium sponge he uses the following solution which is quite analogous to that of Lummer and Kurlbaum for platinizing; one gram of palladium chloride is dissolved in 30 grams of water, and 5 per cent of platinizing liquid is added as a catalyzer.

BATTERIES.

Lead Accumulators for High Discharge Rates.—In the *Electrical World and Engineer* of May 21, W. W. DONALDSON discusses storage battery plate construction with special reference to high discharge characteristics. It is not only in automobile work that high discharge rates are required. The largest field in stationary work where abnormal discharges are used, is where batteries take the peaks of rapidly fluctuating currents, as in tramway stations. The energy of inventors is therefore now directed toward producing plates in which the "time limit of capacity" is small and inversely, the "rate limit of capacity" is large. At present the so-called high discharge rate is four times the normal or eight-hour rate, and the ampere-hour efficiency is hereby diminished to 42 to 58 per cent of the normal capacity. The best plate is the one which, towards the end of its useful period goes to pieces very rapidly and loses its mechanical and electrical efficiency simultaneously. It is the electrical characteristics which should have the first consideration in the design. "Provide for good electrical conditions and the mechanical will take care of themselves." The author offers as a fundamental requirement for both plates that their active material should be formed by an electrochemical action. No paste should enter into the construction of either plate. The positive grid (spongy lead plate) should be integral; no mechanical or autogenous joints should be present. No other metal save pure lead should be used. Castings of the basic plate should be avoided since hard-rolled lead gives a density and homogenity far superior to cast metal. A center web is necessary for the most even distribution of current. Rigidity, in excess of that required for proper elecrical conditions, need only be provided for in direct ratio to the total weight of the plate. Any allowance beyond this reduces the percentage of effective active support. The main conducting and supporting frame, which should never be counted on for any active formation, should not exceed 15 per cent of the weight of the plate proper, and this, with 10 per cent in addition (the residue of the active support) should be all that remains of lead when the plate has lost its useful capacity. The support area for the active material contact should be not less than 175 square inches per pound of plate proper, and should not be greater than 250 square inches per pound of support contact; that is, the thickness of the support contact after formation should not be less than 0.02 inch, which allows 0.01 as a conductor for each layer of active material. The author emphasizes the great importance of the requirement that the metallic contact of the active material support with the main conducing frame should be of such character as not to be impaired by any action due

to subsequent formation of active material. As much of the surface of the active material support as possible should be bathed by free electrolyte, and provision be made for vertical capillary diffusion, rather than for horizontal or through-and-through circulation. This active material support surface presented for discharge action should not be less than 33 square inches per ampere for a rate corresponding to 8 times the normal. The plate as a whole should be as thin as is consistent, and should not exceed ½ inch from face to face.

The author then discusses the lead peroxide plate. The active material must be in the form of a very thin layer, and should not exceed 0.008 inch in thickness, with a conducting backing 25 per cent greater or 0.01 inch thick. Such a layer would correspond to 0.8 of one cubic inch of peroxide per 100 square inches of contact support, or (allowing 2.1 ounces per cubic inch) 1.68 ounces per 100 square inches. This volume of peroxide at a capacity of 2.5 ampere-hours per ounce will give 4.2 ampere-hours per 100 square inches at a normal discharge rate. The ratio of weight of active material to active support should be as 1 to 1.9 and the active material should not be over 18 per cent of the weight of plate proper. The porosity, granular and molecular, should be such as to allow the mass of the active material to hold at least its own weight of electrolyte and thus allow for good diffusion of the acid. Active contact support should be at least 300 square inches per pound of plate proper and grid support 40 per cent of total weight of plate proper. The support contact should not be less than 1/3 that of the active material in thickness. The number of square inches of contact support per ampere of discharge should be no less than in the positive, and although the negative plate is, as a whole, of much lower resistance than the positive, a central diaphragm or wet conductor is of value as the principal starting point and distributer of the current. One all-important necessity for the negative grid is that it should be made in such a way that not more than 10 per cent of its superficial area be exposed to the electrolyte. Less than this amount is often advisable, since the larger the surface of the active material which is bathed by free acid, the better will be the maintenance of the negative voltage on high discharge work. The capacity of the positive should be 60 per cent that of the negative, so that the capacity output is limited by the positive, as working negatives down to low voltages is very deleterious.

Improvements of Accumulators.—The *Zeit. f. Elektrochemie* of April 15 contains a summary of suggestions concerning improvements in storage battery construction, from patent specifications issued in recent years. It is said that by far the greatest part of the patents issued in this line would not have been taken out if the inventors had had some experience in storage battery engineering. Only a small number of new patents refers to practically possible arrangements, and even these represent more or less suitable variations of well-known constructions. Large battery manufacturers do not care for such inventions, which are more or less beautiful in theoretical respect, but practically worthless; they prefer now as simple a construction as possible. Concerning the formation of the active mass, a few purely chemical processes have been suggested, while the majority refers to electrolytic methods. The latter, as far as they have proven effective, are based on the use of an anion, which is capable of forming a lead salt soluble in water. Under suitable conditions, lead peroxide is formed at once from lead, without a previous formation of lead sulphate. It is remarked that this interesting phenomenon appears to be in a near relation to the phenomena of the passive state of iron, chromium and nickel electrodes, and should be studied more carefully.

Influence of Light Upon the Formation of Accumulator Plates.—In our March issue, page 117, we noticed some peculiar observations of Tommasi. In *L'Lclairage Electrique*, M. U. Schoop confirms Tommasi's results and describes the following experiment which he has made. He cut a lead peroxide plate, formed according to Planté, into three pieces, one of which was left in the dark, the second in the daylight, while the third was subjected directly to sunlight. He found that the color of the latter two changed decidedly after some hours. G. Rosset, in the *Centralblatt f. Accum.* sums Tommasi's results up in form of a single law, which is expressed as follows: Darkness favors the oxidation of lead, while light favors the reduction of lead oxide. This general law is a consequence of the phenomena of chemical equilibrium.

Storage Battery Traction.—H. Palitzsch describes in *Elektrische Bahnen*, April, No. 8, a new accumulator car used on the suburban lines of the tramway system of Dresden, Germany. The car, which has a capacity for 98 passengers, is provided with a battery of 184 double cells, each double cell having a capacity of 430 ampere-hours at a discharge rate of 140 amperes. The average discharge voltage is 365. The cells are charged from a station connected in series, the average voltage of charging being 480. When it becomes necessary to charge the cells from a 120 volt circuit they are connected in four parallel groups.

One of those German tramway systems which have used storage batteries on their cars for a long time, but have finally changed their system over to trolley, is that of Hanover. In the *Elektrotechnische Zeitschrift* of May 5, L. Liebenberg describes in detail the new trolly system and gives the following reasons for the change: great danger to the passengers from explosions of gases developed by the batteries; unreliability of the storage battery service; complications and expense involved in the attendance of the batteries.

Daniell Cell as Standard Cell for Technical Purposes.—In the *Centralblatt f. Accum.*, April 15th and May 1, G. Rosset remarks that the Daniell cell is still probably the most extensively used standard cell in technical laboratories. Since, however, the e. m. f. depends upon the concentrations, the e. m. f. is changed by diffusion, evaporation of the liquids, solution of zinc and deposition of copper, so that its e. m. f. is not constant. For copper sulphate solution of specific gravity 1.2 or 1.1, zinc sulphate solution 1.2 or 1.4, Jenkin found the e. m. f. to be 1.099 and 1.069 international volts, respectively. Rosset has therefore endeavored to make the e. m. f. of the Daniell cell independent of concentration changes. He accomplishes this by use of equimolecular solutions of both sulphate and separating them from one another by means of a semi-permeable diaphragm of copper-ferrocyanide, which maintains the concentration of both solutions constant. He has found that under this condition the e. m. f. and the temerature coefficient are constant whatever the absolute concentration of the two solutions as long as they are equi-molecular. The e. m. f. is 1.105 as long as the solutions are not dilute, the temperature coefficient is —0.0002. He produces the semi-permeable diaphragm in an ordinary porous cup, the upper part of which he impregnates with paraffin; he then places the cup into water in order to remove the air from the pores, and fills it with a dilute solution of potassium ferrocyanide (about 4 per thousand); the cup is then placed in a dilute solution of copper sulphate (16 to a thousand). According to the greater or smaller porosity of the mass the diaphragm is then formed from 24 to 72 hours.

Miscellaneous.

The Continuous Steel Process.—The technical journals have lately contained a statement to the effect that the continuous method of making open-hearth steel, which is usually associated with the name of Mr. Benjamin Talbot, and the use of large tilting furnaces, had been adjudged by the United States courts to be the invention of Mr. Ambrose Monell. The statement is erroneous; the Monell process is for a *dis*continuous process in a fixed furnace, and the decision of the court simply affirmed Monell's ownership of his own invention, which Talbot had claimed to have invented also. The idea of the continuous process remains as Mr. Talbot's invention. Recently S. Surzycki has published accounts (*Stahl und Eisen*, Feb. 1,

1904; *Iron and Steel Magazine*, May, 1904), of having worked the Talbot process for two years, at Czenstocha, Hungary, in a fixed furnace, provided with two tap-holes at different levels, the lower one for draining the hearth when necessary, and normally kept closed, the upper for tapping out part, ordinarily half, of the finished steel in the furnace, as in the Talbot process. The rest of the process is as in the tilting furnace, ore is added to form an oxidizing slag, then pig iron, for a sharp reaction, then the bath brought again to tapping heat. The fixed furnace thus worked has its output increased some 15 to 25 per cent, with less wear on the hearth, and in brief unites the advantages of the Talbot continuous process with the cheapness and simplicity of the fixed furnace.

In *Stahl und Eisen* of April 15, 1904, O. Thiel refers to Surzycki's statements, and gives data concerning the application of the continuous process to fixed Bertrand-Thiel furnaces at Hösch. Two such furnaces of 27 tons capacity each, worked in this manner, gave 250 to 270 tons output per day, against 130 to 140 tons obtained from two 27-ton fixed furnaces worked continuously, but not on the Bertrand-Thiel plan, at Czenstochau. At Hösch, the upper furnace receives charges of 1 ton solid Thomas pig iron, 3.5 tons Swedish magnetic ore, containing 63 per cent iron and 1.1 tons of lime. The slag obtained contains 20 to 25 per cent of phosphoric acid. Tapping this metal into the lower furnace, it there receives 3.5 tons of scrap, 0.4 tons of roll scale and 0.7 tons of lime. The steel obtained is very pure, with 0.025 phosphorus, and averages 103 per cent in weight of the pig iron used. These latest developments in the continuous process promise to be of great importance in the open-hearth steel industry. The replacement of the second Bertrand-Thiel furnace by an electrically heated furnace, for the quick raising of the temperature to the tapping point, is well worthy the best attention of electrometallurgists.

Foundry Practice with Copper.—An illustrated article by W. J. REARDON, on practice with copper and its alloys in the foundry of the Westinghouse Electric & Manufacturing Co., is published in the March issue of the *Electric Club Journal*. For casting copper, the first requirement is that it must be heated to exactly the right temperaure, and that the sand must have the proper temper, neither too wet nor too dry. The hardest problem is to produce castings free from blowholes. For this purpose it is necessary to observe the following rules: Heat to exactly the right temperature; have the sand at the proper temper; melt the copper quickly; keep the metal covered at all times; never let the metal stand in the furnace when once ready; add a small amount of silicon-copper (see ELECTROCHEMICAL INDUSTRY, March, 1904, p. 121). In mixing and melting brass, the following simple rules should be observed: Weigh carefully; melt quickly and uniformly; prevent volatization as far as possible; pour at exactly the right temperature. At the present time the temperature is estimated by the naked eye in the Westinghouse foundry. A bearing metal high in lead resembling glyco-metal has been made in the Westinghouse foundry which gives excellent results. It is composed of copper, tin, lead and zinc, and is difficult to make, because of the tendency of the lead, whose specific gravity is high, to settle to the bottom; this difficulty was overcome by devising special methods of mechanical mixing. Another alloy was made up of the same elements, but the mixing was divided into two steps; the first being to make an alloy low in copper and the second to mix it with copper. The intermediate alloy was made by melting the copper first under a charcoal cover, and then adding lead, then zinc, then tin; overheating being carefully avoided. This intermediate alloy was poured into ingot moulds. After cooling it was put into melted copper. The resultant alloy could be cast in sand and withdrawn while still red-hot, without showing any signs of lead sweating out, although the temperature of the casting when withdrawn was far above the melting point of lead. The temperature must be watched very carefully, as a slight excess causes the lead to segregate. Sand for cores should be high in silica and low in alumina, bond being obtained with resin, flour and molasses. Sand for moulding should be fine and open. It should not contain much alumina, because the alumina (clay) bakes, preventing the rapid escape of gas, and so causes blow-holes and sponginess. An illustration is given showing a sand conveyor and moulding machine used in the brass foundry of the Westinghouse Electric Co.

Imperfect Equilibrium in Alloys.—F. Osmond contributes to the May number of *The Iron and Steel Magazine* (formerly the *Iron and Steel Metallurgist*) an account of some attempts made to ascertain the solubility of solid copper in solid silver. Alloys with 0.25, 0.50, 1, 2 and 4 per cent of copper were made, cooled rather rapidly, polished and examined under the microscope while being heated in air up to 500° C. Alloys with 0.25 and 0.50 per cent of copper do not differ from pure silver, showing the copper to be diffused in them in the state of a solid solution; but with one per cent of copper the saturation point of the solid solution is passed, for small particles of copper can be detected by their turning blue, while the metal around them becomes yellowish brown. This indicates a progressive concentration of the copper, an imperfect equilibrium. With more copper present, the eutectic appears, but the silver of the eutectic is shown to contain, by similar tests, an excess of diffused copper, besides its dissolved copper. There is thus shown in these cases a lack of uniformity in these solid solutions. The article concludes with the idea that when a substance in solution, with molecules of the gaseous type, is precipitated from solution at a temperature so low that diffusion is impossible, it may easily retain in solid substances the molecular or even the atomic type, since the isolated molecules or atoms lack the power to unite. The question is a wider one than that of the mere peculiarities of copper-silver alloys.

Manganese and Copper Alloys.—An article in the May issue of *Metal Industry* contains a summary of some investigations on the properties of alloys of manganese and copper.

Tungsten.—E. F. Smith and F. F. Exner presented before the American Philosophical Society the results of an investigation extended over a long period, on the atomic weight of tungsten. An abstract of the paper is given in *Science*, May 6. The authors doubt whether any chemists who in the past occupied themselves with the redetermination of the atomic weight of tungsten have worked with the pure substance. Tungstic acid is prone to form complexes. It was found that if the acid contained no iron, for instance, but be digested with acids, *i. e.*, hydrochloric or nitric acid, in which iron is present, the latter will enter the tungstic acid. Iron and manganese are eliminated from the acid with the greatest difficulty. In earlier work with tungsten, there is no evidence of the removal of iron and manganese nor of vanadium and phosphorus. The authors found that in purifying ammonium para tungstate by recrystallization alone, the tenth recrystallization showed vanadium. The slimy greenish or bluish-white masses believed to be "paratungstates" because of their great insolubility are probably complexes. The use of pure sodium carbonate (2 per cent) to dissolve tungsten dioxide gives an excellent means of ascertaining when the iron, manganese and silica are fully removed, but its development into a method for the determination of the atomic weight of tungsten is not at all probable. The plan of digesting pure ammonium paratungstate with nitric acid, then evaporating to complete dryness and gently igniting, affords pure oxide. Porcelain vessels are preferable to those of gold, silver or platinum for the ignition of ammonium paratungstate and tungstic acid. The oxidation of metal leads to reliable atomic numbers when the material is pure. Tungsten hexachloride can be completely transposed into pure oxide with water and a little nitric acid.

Radium from American Ores.—A paper on this subject was presented to he American Philosophical Society by A. H. Phillips, and an abstract of it is given in *Science*, May 6. The mineral from which the radium was separated was carno-

tite, a new mineral described in July, 1899, and found as yet only in the western part of Colorado and adjacent counties of Utah. In composition it is a potassium uranyl vanadate with three molecules of water of crystallization. The experiments of the author show that carnotite is a carrier of radium to a considerable extent, and would prove a valuable source of radium.

Filter-pressing in Western Australia.—The *Engineering and Mining Journal* of April 14 contains an interesting article by W. A. Pritchard, in which it is stated that more than 70,000 tons of ore and over 15,000 tons of accumulated tailings are treated monthly at Kalgoorlie by filter-pressing. This constitutes over 80 per cent of the output. Outside of Kalgoorlie, many of the mines of Western Australia are passing from 25 to 50 per cent of their ore through filter-presses. It will thus be seen that this process plays an important part in the extraction of gold. The filter-press in Western Australia has developed from a center-filling, hand-closing press, making one-inch cakes to a press filled on the side, closed by hydraulic pressure and making three-inch cakes. It is used solely for the purpose of extracting gold solutions from pulp, which is too fine for leaching, and for drying gold precipitates from zinc boxes. The gold solution, after filtering, is ordinarily pumped through clarifying presses to remove any fine slime which has passed through the cloths; it is then delivered to the precipitation boxes. In spite of unfavorable conditions for power, water and labor, the cost is not high. A pretty full description is given of the details of the method and of the construction of the presses.

De-tinning.—A note on a new process for winning tin from tin scrap is published in the April number of *Metal Industry*. Coke is crushed to a coarse powder and saturated with a strong solution of common salt, any excess of solution above that required to saturate the coke being drained off, so that the air is able to penetrate readily throughout the mass. The scrap to be stripped is covered with this moistened coke powder. The action commences very rapidly and is often complete in a few hours. To avoid patches of unstripped material on the surface of the scrap, it is well to cause the heap to be shaken from time to time, so that the whole of the tin surface of the scrap is brought into contact with the coke. When the black surface of the scrap shows that the separation is complete, the mass is washed with a jet of water, when it is found that the tin is washed out in the form of an oxide, probably in the form of hydrated stannic oxide, which forms a white milky precipitate in the water, from which it can be collected by allowing it to settle and subsequently filtering it off. No tin is found in the solution as chloride. The brine-moistened coke can be used over and over again, so long as the heap does not become too dry. The rough coke powder is separated from the stripped scrap by means of a screen, and when this is done the coke may be allowed to fall into unstripped scrap; the stripped scrap left on the screen being then well washed with a water jet, as a large amount of tin oxide adheres to the surface.

Determining Ozone in Gases.—A brief Faraday Society paper by E. G. P. Bousfield deals with the accurate determination of the percentage of ozone in gases not dissociated by moderate heat. It is published in the March issue of the *Electrochem. and Met.* The method is based on measurements of volume and the principle is to measure first a certain quantity of the gas containing the ozone; this gas is then passed over some substance which is capable of converting ozone into ordinary oxygen (like platinized asbestos, gently heated). On again measuring the gases, an increase of volume, due to the breaking down of O_3 molecules into O_2 molecules is found. From this increase of volume, the quantity and percentage of ozone originally present is readily calculated.

Copper Cyanide Solution.—The colorless solution of copper cyanide which is not precipitated by sulphuretted hydrogen, and which is familiar to all students of qualitative analysis, has been studied by J. B. Treadwell and C. von Girsewald, the results being given in *Zeit f. Anorganische Chemie*, and abstracted in *Eng. and Min. Jour.*, March 31. The formulas given in text books $K_2Cu(CN)_4$ and $K\,Cu(CN)_2$ are apparently merely guesses. From a study of solutions containing various proportions of copper and potassium cyanide, the authors conclude that the salt present is $K_4Cu_2(CN)_6$, the ion not decomposed by hydrogen sulphide being determined as $Cu_2(CN)_6$.

Plating of Sheet Zinc.—After a review of the development of plating upon zinc, it is said in an article in the *Lead and Zinc News* of April 4, that in recent years the cost has been considerably reduced by plating the zinc sheets, with nickel before stamping and working them into shape. The sheets can be plated and polished at about one-half or one-twentieth the cost of the finished article. Zinc is the best base for the production of such sheets, as when cut it has a white edge which is very close to the color of the polished nickel. The cheapness of this base compared with brass and copper, to which it is equal in resisting oxidation, is a strong point in its favor. Sheet zinc coated with nickel is known in Germany as nickeline, but the industry has also been introduced into this country. The nickel is plated directly on the zinc without a previous coating of the zinc with copper. Zinc is also coated with copper and brass. The brass-coated article is often lacquered with a transparent lacquer, colored with a suitable coloring, and the finished article obtained with the color and appearance of gold. The copper finish is oxidized, spotted and lacquered, and then takes the place of the popular finish commonly known as antique or oxidized copper.

Firebrick.—A note in *Metal Industry*, April, refers to the selection of the proper kind of firebrick. It is pointed out that for a crucible furnace, hard firebrick is needed with a smooth surface and close grain, of the highest heat-resisting nature possible in connection with the other properties, and of a chemical nature, as near as possible to that of the clinker, so that there shall be no fluxing action, and consequently no abnormal adherence of the clinker to the brick.

Insulation for Wires.—In an article in *L'Electricien* of April 2, some uses of the Hackethal wire are mentioned. Its feature is the insulating material which is formed of a vegetable tissue impregnated with linseed oil and minium. The wire is stated to be used in telephone lines in Germany, and to have given good results in chemical works on account of its resistivity against the corrosive action of an atmosphere saturated with acids. If too strong a current is passed through the wire the insulating material dries out and is carbonized, but does not burn.

Fuel Economy from the Chemical Point of View.—A paper was read on this subject before the Liverpool Engineering Society by J. R. C. Kershaw, and a longer abstract is published in *Elec. Rev.*, of May 21. The author first deals with the fuel and water supply and recommends that, besides the steam-raising trials made with the fuel, thoroughly reliable samples of the fuel should be submitted to chemical and calorific examination, and that the results obtained in the trial under the boiler should be judged in the light of these laboratory results. He recommends an approximate analysis of the fuel, giving the per cents of volatile hydrocarbons, of ash and of fixed carbon. As long as the contract for the fuel supply runs, samples should be taken at intervals and submitted to analysis. The feed water should also be tested at quarterly or shorter intervals, since the amounts of lime and carbonate of soda or caustic soda for softening, depend upon the condition of the water. The author then deals with the combustion of the fuel in the boiler furnace. Perfect combustion of bituminous coal requires a sufficiency, but not an excess, of air; a sufficiently high temperature in the combustion chamber; and a perfect admixture of the air and volatile hydrocarbons. These requirements are discussed in detail. Examination of the waste gases is demanded; it should include the temperature of the exit gases, the draught behind

the chambers, and the chemical constitution of the gases. The author believes that if boiler engineers would pay more attention to the chemical side of their work, their annual fuel expenditure would be materially reduced.

Utilization of Peat and Lignite.—The question of the utilization of lignite and peat for power purposes is one of great commercial importance for various countries, and has been the subject of extended investigations. In an article in *Eng. and Min. Jour.*, April 7, H. H. WOTHERSPOON gives an account of recent advances made in this direction, especially in Germany. The principal deposits of lignite from which briquettes are made, exist in two different parts of Germany which include over 280 factories for the manufacture of the briquettes having a total of 680 presses. The output for 1902 is given as 12,438,000 metric tons; most of this fuel was consumed in the larger cities of Europe. The process of converting brown coal into briquette form consists in "developing the latent bituminous matter within the lignite by the aid of heat, and then compressing the same in powerful tube-presses which have a capacity of 60 tons per twenty-four hours." The wholesale selling price of these briquettes in the larger German cities is between $2.10 and $2.25 per metric ton. The brown coal of Alabama has been briquetted by this process quite successfully, and has been declared by the German experts to be superior to the best product from their own mines. The calorific value of these briquettes is between 7,500 and 9,000 B. T. U., depending upon the quality of the raw material. It is also stated that the advance in Germany in the manufacture of bog matter into fuel is quite remarkable. The rapid loss of water is stated to be due to "the mechanical processes through which the material is put on leaving the bog. The machinery which rapidly and thoroughly breaks up the cellular structure of the partly decomposed vegetable matter, sets free the water from the plant fiber and develops the peculiar vegetable mucilage or natural binding matter contained in the mass. After the peat has been thoroughly pulped, it is passed into compression tubes. Part of the moisture contents is here squeezed out of the mass, and the remainder evaporates rapidly on exposure to the air making a dense, clean, elastic fuel after about two weeks' time." Fuel bricks are clean to handle and practically smokeless, and they have a calorific value of between 8,500 and 10,000 B. T. U., Norton's figures, for the thermal value of American bogs range between 9,000 and 14,000 B. T. U. per pound, when bone-dry.

Castner.—In our January issue, 1903, we gave a reproduction of the Castner memorial tablet in Havermeyer Hall, Columbia University, and gave a brief account of the ceremonies of the unveiling of that tablet. The addresses delivered on that occasion are now given in full in the School of Mines Quarterly, January, 1904.

FARADAY SOCIFTY MEETING.

The May meeting of the Faraday Society was held on May 9 at the Institution of Electrical Engineers in London, Mr. Bertram Blount in the chair.

STUDIES IN VISCOSITY.

Dr. Charles E. Fawsitt delivered a paper on this subject, in the first part of which he discussed some relations of viscosity to salt formation. The viscosity of a mixture of two or more substances in aqueous solution is equal to the product of the viscosities which the solutions of the substances separately have. If, however, the substances act chemically on one another, then the viscosity of the mixture is different from the calculated value. By numerical illustrations from cases where a strong acid is neutralized by a strong base, this difference is shown to have a constant value for equimolecular quantities. This value corresponds to the formation of undissociated water from the hydrogen and hydroxyl-ions. The difference between the calculated and observed values in the case where a weak base is mixed with a strong acid has a value which varies with the base in the case of urea and its derivatives appears to vanish.

In the second part of his paper the author dealt with viscosity as an additive property. A comparison of the viscosity constants of some urea derivatives and aurides of the fatty series shows that for a difference in the composition of CH_2 there is a corresponding difference in the viscosity constant. There is, however, a pronounced "constitutional" effect as shown by the different values obtained for isomeric substances.

In the discussion which followed, Mr. B. Blount referred to the difficulties in making accurate and reliable viscosity measurements on which important deductions are based. Dr. T. M. Lowry discussed the relationship between viscosity and conductivity for varying temperature, and showed how, in the case of very dilute solutions, the conductivity-temperature curves converge to zero conductivity at 39° C., just as the viscosity curve for pure water does. Dr. Rudorf observed that with different forms of apparatus different results are obtained. Dr. Fawsitt in reply said that his results were all obtained with one apparatus and that they were strictly comparable. Referring to Dr. Lowry's remarks he added that viscosity is inversely proportional to migration velocity.

THE ELECTROLYTIC OXIDATION OF ANTHRACINE.

A paper on this subject by Mr. A. Fontana and Dr. F. M. Perkin was then read by Dr. Perkin. The authors have taken up the study of the oxidation of anthracine primarily to ascertain whether it is possible to obtain a good laboratory method for the preparation of anthraquinone. The first attempts were made with solutions in acetone, platinum electrodes being employed. Although oxidation took place in solutions of anthracine in acetone, it was not found possible to oxidize more than about 55 per cent of the anthracine. Attempts were then made to electrolyze anthracine suspended in 20 per cent sulphuric acid or in caustic alkali to which an oxygen carrier had been added. Various carriers were employed, the most satisfactory being chromium, cerium or manganese salts. The anode consisted of a lead vessel; the cathodes, four in number, were also of lead and were placed in four small porous cells. There was also a lead paddle which was connected with the positive pole, the total anode surface was about 6 square decimeters, the current density 1 ampere per square decimeter, the temperature 70° to 80° C., and the e. m. f. from 2.5 to 3.5 volts. The yield of anthraquinone was about 80 per cent, and it was not found possible to increase the yield more than 1 or 2 per cent above this. It was afterwards found that almost equally good results were obtained without a diaphragm. In this case the stirrer ½ square decimeter in area was made the cathode. In discussing the results of their experiments the authors consider that owing to its volatility and the comparatively poor yield a solution in acetone cannot be recommended. On a large scale no method in which a diaphragm is employed would be satisfactory, owing to the migration of the SO_4 ions from the cathode to the anode side. They then briefly review the patents of the Höchster Farben Fabrik, Darmstädter and Martin Moest. Le Blanc has criticised Darmstädter's patent, and doubted whether it would be possible to obtain any appreciable quantity of anthraquinone owing to the reduction of the chromate by the cathodic hydrogen. The authors are of the opinion that to a certain extent the chromium, managanese and cerium salts act as chromium does when employed in the electrolytic bleach industry, viz., by preventing reduction. Moest claims, in his patent, to obtain a hundred per cent yield of anthraquinone; the authors have been unable to obtain much more than 80 per cent; they are, however, of the opinion that very likely better results would be obtained on a manufacturing scale.

In the discussion which followed, Mr. Blount suggested the use of thallium salts. He thought the energy bill in this instance might not necessarily be an all-important item. Dr

Steinhart thought better results would be obtained if the anode solution were removed from the cathode. Mr. Inglis discussed the effect of the potential difference between the anode and solution. Mr. Gaster thought the cost of energy was of prime importance. He suggested the use of petroleum as a base for colors instead of tar.

Current Notes.

Philadelphia Section American Electrochemical Society. A meeting of the Philadelphia Section was held at the Engineers' Club on May 6. Dr. J. W. Richards read portions of his presidential address delivered at Washington, and led a discussion of some of the principle points, in which various members participated.

Titanium Trichloride.—With reference to recent French and English patents on the reduction of titanium tetrachloride to titanium trichloride, a correspondent calls our attention to a paper published by E. Polidoni in 1899 on the electric reduction of titanium tetrachloride to trichloride. (See *Zeitschrift f. anorganische Chemie*, v. 19, page 306; *Chemisches Centralblatt*, 1899, v. I., p. 518.) The industrial importance of titanium trichloride is due to its strong reducing properties, as well as to its use for etchings and dyeing leather, silk, etc.

American Electrochemical Society.—At a meeting of the Board of Directors, held on May 7, it was decided that a monthly bulletin be sent out by the Secretary, to include the names of applicants to be voted upon at the next Board meeting and those elected at the one preceding and as far as possible all notices that should be sent out for the current month. The first bulletin has just been issued. It states that the following gentlemen were elected members: Herbert Haas, Redding, Cal.; C. J. B. Henning, Santa Cruz, Cal.; Franz von Kügelegn, Holcombe Rock, Va.; F. H. Chapin, Minneapolis, Minn.; H. W. Buck, Niagara Falls, N. Y.; Henry N. Stokes, Washington, D. C.; Prof. F. H. Wolff, Jr., Washington, D. C.; H. W. Sykes, Syracuse, N. Y.; Charles Brandeis, Montreal, Canada; Charles H. Clarke, Berlin, N. J.; Horace H. Emrich, Perth Amboy, N. J. At the next meeting of the Board, action will be taken on the following applications for membership: George Breed, Philadelphia, Pa.; Alexander Lodyguine, Staten Island, N. Y.; Charles Jackson, Guadalajara, Mexico. The date of the St. Louis meeting is provisionally set for the 13th to 16th of September, inclusive. Sessions on two days will be held jointly with Section C of the Fifth International Electrical Congress, one sesion will probably be arranged to be held jointly with the Bunsen and Faraday Societies, and one independently.

Water-Power Developments.—A note in the twelfth annual report recently issued by the General Electric Co. should be of specially great interest to our readers. One of the important enterprises completed last year by this company is a power transmission plant at Guanajuato, Mexico. The power is transmitted at a continuous pressure of 60,000 volts. The transmission line is 101 miles long and the wires are carried on iron towers 48 feet high and 440 feet apart. Including steam and water-power plants, the General Electric Co. has installed and under contract at present 1,230,270 hp. capacity in polyphase generators. Of these, 514,910 hp. capacity are being operated by water-power.

Fixation of Atmospheric Nitrogen.—We understand that the Niagara Falls plant of the Atmospheric Products Co. has recently discontinued operation, but no authoritative information could be obtained whether this discontinuance of work is only temporary.

The Radioactive Atom.—Thomson, in a paper abstracted in our April issue on the structure of the atom, starts from the assumption that an atom is made up of electrons, and then goes on to determine by the rigid rules of mathematical physics, what structure must necessarily be attributed to the atom as consequence of this original assumption, and finally compares the results at least to some extent quantitatively with the experimental facts. In two recent pamphlets of A. Reuterdahl similar problems are discussed in a more speculative and qualitative way, the author giving a picture which he has made for himself on the structure of the atom to explain the facts, especially those on radioactivity and electrolysis. In a pamphlet on "the radioactive atom (Providence: *The Franklin Press Co.*, 1904) he gives, with the aid of diagrams, his views of the structure of the atom. He considers it as a highly complex structure, ultimately composed of very minute particles which he calls "energons" and assumes them to be simply "centers of activity." On account of the radioactive phenomena which he endeavors to explain, he calls his atom the "radioactive atom." It is made up of a spherical shell consisting of energons. Within the interior of the shell fairly stable groups of energons have room to exist. Groups of six energons he calls "dynamicons." When certain conditions exist, the energons constituting the shell have the power of attracting to themselves particular electrons from the space surrounding the shell; a rearrangement of the energons composing the shell takes place, and new energon groups may be formed, which pass into the interior of the shell. The author refers to Hovenden's theory of a substance or fluid which, when uninfluenced by external forces, rises from the surface of the earth or "anti-gravitates." But while Hovenden considered the rigid and incompressible ether to be this substance, the present author assumes it to consist of energon groups which possess a fair amount of stability, but may, nevertheless, be decomposed and undergo changes when subjected to the proper conditions. He applies the term dynamicon to this anti-gravitating substance. When a substance changes its state, for instance, from the liquid to the gaseous condition, the quantity of dynamicons within the radioactive atom also changes. Any increase in the number of dynamicons within the shell is accompanied by an increase of the number of energons constituting the shell. The expansion of the energonic shell begins, due to an excessive inflow of dynamicons, then the assimilative property of the shell also begins to exert itself and energons are added to it in such a compensating manner that the net attraction between the atom and the earth is at all times proportional to the established atomic weight. The chemical combination of atoms into molecules consists essentially in one atom entering into another, and becoming concentric with it. The radioactive atom may be considered as being provided with "polar openings." The alignment of these polar openings is termed "polarization;" it takes place when an e. m. f. is applied. The phenomenon of heat is a reaction between the energonic shell and the dynamicons. The phenomena of the electric current consist in a flow of dynamicons. The activity of the radium atom consists in continuously manufacturing dynamicons and other energon groups from surrounding energons and ejecting or radiating these manufactured products into the surrounding space.

Electrolysis According to the Energonic Hypothesis.—A. Reuterdahl's second pamphlet (Providence: *The Franklin Press Co.*) deals with this subject. He sketches the fundamental ideas of the dissociation theory and emphasizes that there must exist vast differences between the ionic and atomic conditions (a statement which has never been earnestly denied by anybody). When a solute is dissolved in a solvent, the author assumes the atoms and molecules to enter into reaction; there is a condition of a strain or tension between solvent and solute, which is due primarily to the ultra-atomic affinities between the energonic shells of the atoms and molecules involved ("herein lies the explantion of the real nature of osmotic pressure and solution tension; they are one and the same phenomenon, *i. e.*, ultra-atomic activity"); it is always the endeavor of every atom to absorb the maximum amount of dynamicons which its nature allows; equilibrium is reached when

the distribution is uniform throughout all the atoms and molecules involved. In certain well-defined cases there may occur an unlocking of the ions which constitute the molecule; this phenomenon "consists merely in a partial separation and increase in the distance between the adjacent energonic shells of the anion and cation. When this action is still further enhanced by the application of the electric current, for example, then the distance between the shells of the anion and cation may be augmented sufficiently to allow the cation to pass out of the anionic shell, thus becoming actually free and dissociated." The phenomena taking place in a simple concentration cell are explained by the author by the anology of the ordinary lift pump.

Correspondence.

ELECTROCHEMICAL NOTATION.

To the Editor of Electrochemical Industry:

Sir.—In your issue of November last you published an editorial urging a thorough discussion of the advisability of a uniform international notation in electrochemistry in the columns of the engineering and scientific press, in advance of the international congresses to be held in St. Louis, this autumn.

I heartily concur with you in this matter. A fixed rule of notation should be established, but this cannot be done by simply adopting a resolution by a congress. Any recommendation should be thoroughly discussed in advance. There should be no ambiguity in future in the use of terms, like conductance and conductivity, or positive and negative plate of an accumulator; such handy abbreviations, like mol. for gram-molecule, should come into general use; and above all, when electrochemists decide to adopt a notation, they should adopt one which agrees with the notation of electrical and mechanical engineers. With respect to the latter point the table of the German Bunsen Society, on page 542 of your November issue, seems to be open to many objections.

What I wish to emphasize is that now is the time to start such a discussion and every electrochemical scientist and engineer interested in this subject should now express his opinion. A. N. H.

New York.

[We fully agree with the sentiment expressed by our correspondent and will gladly open our correspondence columns to those interested in this important subject. Ed.]

Book Reviews.

Chemiker Kalender, 1904. By Dr. R. Biedermann, with an appendix. Berlin: J. Springer. Price, 4 marks.

This well-known German almanac for chemists, physicists, metallurgical engineers, etc., is now published for the twenty-fifth time. The general arrangement has not been changed since its last issue, while the results of recent researches have been made use of in correcting details. For the use of logarithms a short and clear explanation has been given; experience has shown that this is not superfluous for many chemists in laboratories as well as factories.

The tables of inorganic compounds (40 pages) and of organic compounds (124 pages) should be appreciated by American chemists and engineers, since they are arranged alphabetically according to the German name which is followed immediately by the chemical formula. These tables therefore form an excellent dictionary of chemical compounds which should be extremely useful for foreigners when reading German chemical literature. Besides the German name and the chemical formula, these tables give the molecular weight, notes on crystallization and color, the density (with respect to that of water or air as unity), the melting point, the boiling point and the solubility in cold or hot water, as well as in alcohol, acids and alkalies (for inorganic compounds) and the solubility in water, alcohol and ether (for organic compounds). Then follow extensive tables of the specific gravity of various solutions, of solubilities, and on analysis. It should be acknowledged that the advances made in electrochemistry have found due consideration.

Die Metalle, Geschichte, Vorkommen and Kewinnung, nebst ausführlicher Productions-und Preis-Statistik: von Bernhard Neumann, Halle: W. Knapp. 421 pages. Price 16 marks.

The author is a professor of the Technical High School at Darmstadt, and the work was written to the order of the German Society for Trade Improvement, and afterwards awarded a prize by them.

The work is the outcome of industrious compilation and abstraction from larger works, and as such has a certain value. It deals with all the metals, even the rarest ones, and therefore will not entirely disappoint the reader in any line. The *History* is in each case necessarily brief, but nevertheless well written up to about 1900; from there on, unreliable. The antiquarian part of the history has received most attention. The *Occurrence* in nature is very briefly dismissed. The *Manufacture* is, like the history, more complete in its antiquarian aspects, and less satisfactory in regard to the processes now actually in use. The *Statistics* of price and production form the part of the book really of the most value, for the compiler has collected from many difficultly-accessible sources data which are seldom given in books on metallurgy, such as price and production in ancient and medieval times, and so on continuously to the year 1902. Numerous clearly-drawn and well-lithographed plates enhance the value of this part of the work.

To the electrometallurgist or chemist, the book will be valuable, principally for the statistics; although some interesting data may be, perhaps, extracted from the antiquarian part of the history and processes of manufacture, the rest of the work will not have any claims on his attention. There is a class of readers, however, to whom the work as a whole, will be particularly valuable, viz., to students of political economy and industrial economic development. For such, the treatment is well-balanced and the data accumulated of great importance, and in a form easy to understand and utilize.

Soda Caustica, cloro e clorati alcalini per el trolise: per Ingegnere Fabio Villani. Milan: Ulrico Hoepli (Hoepli Manuals). 16 mo., 314 pages. Price 3.50 lire.

This is a beautifully printed book, as are all the Hoepli manuals, and contains much useful information. The work is divided primarily into two parts, electrolysis by the wet way and the dry way (fused salts), but as the former covers 300 pages, and the latter only 15, we begin to suspect a lack of balance in the treatment. This impression is deepened when we search the book for the detailed description of processes, and find *only* that of the *"Villani* electrolytic bath, with continuously depolarized anode," the process using managanese dioxide as an anodic depolarizer. As far as the reader of the book would be instructed by it, the processes of Castner, Kellner, Hargreaves and Bird, Acker, etc., in fact, all except that of Villani, might as well be non-existent.

If the book be taken simply for what it is, viz., a description of Villani's apparatus, and a detailed account of the information which he made use of and that which he acquired in conducting his experiments, then the reader need not be disappointed. The chapter on the volumetric analysis of the solutions used, and especially that on the control and chemical surveillance of an electrolytic plant producing caustic soda and bleach, are replete with valuable practical information for anyone working in this branch of manufacture. The specialist in this business who can read Italian will find the book certainly well worth getting.

Die Elektrolytische Raffination des Kupfers. By Titus Ulke. Translated into German by Viktor Engelhardt, Halle: W. Knapp, 1904, 152 pages, illustrated.

This is the tenth volume of the Monographs for Applied Electrochemistry, issued by this well-known German publishing house. It is a translation of Ulke's well-known book on copper refining into German. The original American edition was reviewed in our number of December, 1903, page 594. Nothing appears to have been added in the German translation, which evidently has been well and carefully prepared.

TWO STORIES OF ZINC.

A very neat pamphlet issued by the Lanyon Zinc Company contains two well-written stories of zinc which give a very clear exposition of the general principles governing the various steps in the reduction of spelter from ores and in the making of sheet zinc.

The "Story of Spelter" is first told. The principal ore supplies of the Kansas zinc smelters come from the Joplin district. On arrival at the smelter they are transferred to huge bins, which hold hundreds of tons. There the ore is dried. Afterwards it is crushed to uniform size to be treated in the roasting or calcining kilns. Calcining or desulphurizing is a simple but very important process during which the zinc is changed into zinc oxide, while the sulphur passes off as sulphur dioxide. The collection of the fumes and their subsequent condensation into sulphuric acid affords a handsome source of income to the United Zinc & Chemical Co., the only smelter west of the Mississippi River which makes any attempt to save this product. Several devices are described for stirring the ore, so as to expose each little particle to the oxidizing action of the heated air. It is not necessary to maintain an extremely high heat in the calcining kilns, a temperature of 1700° F. being the general average in use. This temperature is not kept uniform throughout the length of the kiln, but is gradually increased as the period of calcination progresses.

From the calciners the ore is conveyed to store houses where it is graded according to metallic contents. As needed for smelting, the ore is conveyed to a "mix-room," where it is mechanically mixed with finely ground coal and fairly coarse coke or coal, as reducing agent. The mixture is then treated in the distillation furnace which is described at some length and illustrated, while a sketch is given of a day's work in a distillation furnace plant. Despite many efforts of the metallurgists of the world, the losses of zinc in the process of distillation are greater than the losses of extraction of any other metal. The losses average from 10 to 30 per cent of the metallic contents of the ore and are largely due to the passage of zinc into the materials which compose the retorts, the escape of zinc fumes through the pores of the retorts and cracks therein or by the breaking of the retorts, producing entire loss of the charge in these receptacles. Some of the zinc vapors escape through the condensers and still another loss is incurred in cleaning out the retorts, while preparing them for a new charge, the latter loss being unavoidable.

The "Story of Sheet Zinc" is next told. Some historical data on this industry in the United States are first given. It is mentioned that the operation is one requiring skilled help and constant watching, lest any one of a score of contingencies arise. Only the choicest of spelter can be used in sheet zinc manufacture. Once the selected slabs of spelter reach the zinc rolling mill they are fed into a huge melting pot which has a capacity of 15,000 to 35,000 pounds of molten semi-fluid metal. From this huge pot the metal is withdrawn by the aid of huge ladles and poured into moulds, usually 10 by 30 inches, and an ingot or billet is cast, having a thickness from one to three inches, depending upon the size and thickness of the sheet to be rolled. After the zinc has had time to cool in the moulds the billets are passed on to a room in which they are annealed at a temperature of about 300° F. A moderate change in the temperature of the annealing oven will cause a variation in the character of the sheet produced from the annealed metal. This peculiarity is a subject little understood by the average consumer of sheet zinc, and were he to take advantage of this fact, he could frequently secure sheets more perfectly adapted to his particular business by advising the rolling mill of the particular use to which he intends putting the sheets; they would then be made accordingly.

From the annealing oven the billets go direct to the first or "roughing" rolls. The sheet is then sent to power shears—great knives which clip off the edges of the sheets of metal. They are then cut in half and are passed through a second annealing oven where they are subjected to a temperature of from 350° to 400° F. for a period of about two hours, and then gathered into "packs" consisting of 18 or 20 sheets, and in these packs sent to the finishing rolls. The finest and most delicate step of the process is the finishing. The margins of the sheets are finally again trimmed off by power shears and the sheets are inspected for flaws, and are packed.

The use of sheet zinc in the United States has been growing steadily for years. From a total production of about 3000 tons of sheet zinc in 1873, the consumption has increased more than ten-fold. Among the more common uses of sheet zinc are the manufacture of metallic ceilings, stove boards, the linings of refrigerators, fruit jars, tops, etc., and large quantities are used in the precipitation of gold from cyanide solutions. The use of small galvanic batteries takes quite a large tonnage of this metal in the course of a year, since it has been demonstrated that batteries and rods made from sheet zinc are of a more satisfactory character than those which are cast. To-day for 90 per cent of the newspaper illustrations of the United States, or half-tones which are made, sheet zinc is used. Paper and fine cardboard makers, as well as lithographers, use large sheets in their various lines of work.

Since sheet zinc is capable of very excellent treatment through the process of turning and stretching, these sheets are to-day entering into formidable competition with sheet brass and copper, being plated with copper or brass as the articles are made up. The manufacture of nickel, copper and brass plated zinc sheets is as yet comparatively young in the United States, although the prospects for this line of work are very excellent. Skilled workmen are constantly developing new uses for sheet zinc, and there is to-day no reason to doubt that the next decade will see the demands for sheet zinc more than doubled.

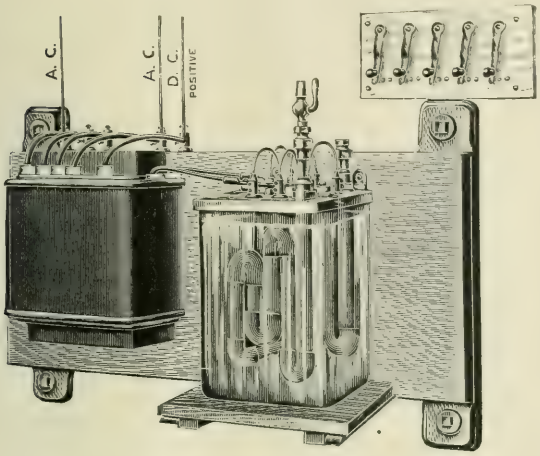
The pamphlet is well printed and nicely illustrated with various pictures in the text, while two larger illustrations are added, one showing the Iola plant of the Lanyon Zinc Company, which is the largest zinc smelting plant in the United States, and the other giving a typical view of a zinc furnace in operation, showing the tongues of zinc and other vapors escaping from mouths of the condensers. A map of the United States zinc mining camps is also given and the towns are marked in which zinc smelter are located.

ELECTROLYTIC RECTIFIER.

In our February issue (page 76) we published a description of the Churcher electrolytic rectifier, made by the Electric Appliance Co., of Cincinnati, Ohio. Its characteristic feature is that it is used in connection with a transformer, the secondary of which is tapped in the center, and is there connected to a platinum plate in the rectifier, while the two terminals of the secondary are connected to two aluminium plates. During one half-wave of the alternating current, one-half of the transformer is active; during the next half-wave the other half-wave, and so on.

The adjoining illustration shows an electrolytic interrupter, also made by the Electric Appliance Co., of Cincinnati. This interrupter gives promise of extensive application in the X-ray field, as it is a well-known fact that alternating current is very inefficient for such purposes, especially when the frequency

is over 60 cycles. The Churcher alternating rectifying interrupter will receive any potential, any phase or cycle of alternating current and deliver a rapidly and completely interrupted direct current through the primary of an induction coil. Its construction and mode of operation is similar to the

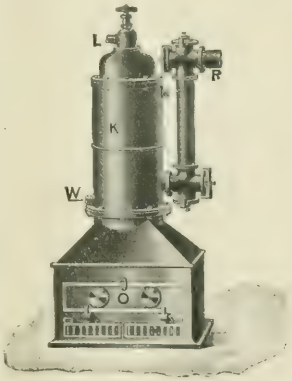


ELECTROLYTIC RECTIFIER.

Churcher rectifier, the only difference being in the area of exposed contact of the positive electrode, which, in this case, is of restricted area; restricted to such a degree that instantaneous interruption of the current is obtained by the well-known Wehnelt effect. Adjustment is possible by the regulation of the amount of positive electrode exposed.

SULPHUR FURNACE.

The adjoining illustration represents a sulphur furnace, made by the Schutte & Koerting Co., of Philadelphia, the applications of which are quite manifold. It is especially applicable for bleaching sugar, starch, glue, gelatine, etc., in the chemical industry, further for sulphurizing and preserving hops in breweries; and for disinfecting purposes.



SULPHUR FURNACE.

This furnace consists of four main parts. First, the bottom part, the pan in which the sulphur burns. A regulating device is here provided for controlling the supply of air for burning the sulphur.

The second part is the cooler K, which is cast in one piece, and through which water flows to cool down the gases, so that the latter do not reach the saturating tanks at too high a temperature.

The third main part is the cap covering the cooler and the fourth main part is the exhauster working by steam or compressed air, according to the circumstances, to draw the gases through the cooler and to discharge them under pressure through the outlet pipe, or suck them through the outlet pipe.

According to the application, either one or the other method is used. In some cases it may be advisable to have the steam mix with the sulphur gases, and then the exhauster is placed behind the tanks to be sulphurized. The furnace and cooler are made of cast iron, and by taking off the top cap the whole apparatus, especially the pipes in the cooler, through which the gas flows, is exposed for cleaning and renewals. The exhauster is fitted with a spindle, both for adjusting the discharge pressure and (within certain limits) the supply of air to the furnace.

The advantages which the Schutte & Koerting Co., as manufacturers, claim for this sulphur furnace, are low price, simple construction and small space required; certainty and regularity of working, absence of variation in volumes of gas produced; absence of moving parts, with a resulting saving in wear and tear; no necessity for skilled attendance.

INDUSTRIAL NOTES

THE FOOTE MINERAL CO., of Philadelphia, has recently issued a nicely illustrated new abridged edition of their catalogue of mineral collections, individual specimens and laboratory minerals, for schools, colleges, teachers, chemists, assayers, students, mining experts, etc.

We have received from THE LEEDS & NORTHRUP CO., of Philadelphia, their illustrated catalogue of electric testing instruments, dealing with condensers, galvanometers, bridges, resistance boxes, testing sets, potentiometers, etc. The description of the Leeds & Northrup potentiometer should be of special interest to electrochemists.

THE SCIENTIFIC MATERIALS COMPANY, of Pittsburg, Pa., has just issued the 1904 edition of its voluminous catalogue of apparatus and supplies for chemical and biological laboratories. The catalogue comprises 436 pages, and is one of the most complete lists of chemical laboratory apparatus which exists. The arrangement is alphabetical, according to the names of the apparatus, so that it is very easy to find what one is looking for. Each apparatus is briefly characterized and its main features are pointed out. Very often the apparatus are illustrated. The list of balances alone comprise 37 pages.

PERSONAL.

MR. WOOLSEY MCA. JOHNSON, of the Lanyon Zinc Co., was recently in New York.

MR. C. O. BAKER, president of Baker & Co., incorporated, of Newark, N. J., and New York City, the well-known refiners and artisans in platinum, gold and silver, sailed on Wednesday, May 18th, on the White Star Steamship "Cedric," for his annual trip abroad.

The St. Louis World's Fair has started and foreign engineers and scientists are beginning to arrive. Among the gentlemen whom we had the pleasure to see in our office were Dr. O. Weil, chief chemist of the thermit department of the Goldschmidt works in Essen; Mr. F. Froelich, who represents the Verein Deutscher Ingenieure at the St. Louis Exposition, and Dr. Leopold Rostosky.

DIGEST OF U. S. PATENTS

PRIOR TO JULY, 1902.

Compiled by Byrnes & Townsend,
Patent Lawyers,
National Union Building, Washington, D. C.

PRODUCTION OF ALUMINIUM FROM FUSED ELECTROLYTES.

(*Concluded from page* 210.)

527,846, October 23, 1894, Leonard Waldo, Bridgeport, and Frank A. Gooch, New Haven, Conn.

Injects hydrogen into fused baths of aluminium compounds which liberate chlorin and fluorin when electrolyzed. The

hydrogen combines with the halogens and the resulting hydrochloric and hydrofluoric acid gases are removed by a draft flue over the vessel, or by endless belts of fabric running through water and over the vessel. The hydrogen also agitates the bath, protects its surface from the action of the atmosphere and prevents corrosion of the anodes by the halogens. The hydrogen may be introduced through a tubular carbon anode. A platinum anode may be used. The preferred bath comprises: Cryolite, 55 parts; aluminium chloride, 12 parts; magnesium chloride, 5 parts; sodium chloride, 28 parts. The bath is replenished with aluminium chloride only. E. M. F., 4 to 10 volts.

527,847, October 23, 1894, Frank A. Gooch, New Haven, and Leonard Waldo, Bridgeport, Conn.

Introduces water into fused baths of aluminium compounds which liberate chlorin or fluorin when electrolyzed, to remove the halogens as acid gases. Appartus same as in 527,846. Steam may be injected near the anode or through a tubular anode; or a water spray or small pieces of ice may be dropped under the bath. Steam tends to oxidize the carbon anodes. The preferred baths are: (1) Aluminium sodium chloride, 15 parts; cryolite, 55 parts; sodium chloride, 30 parts; or (2) Cryolite, 55 parts; aluminium chloride, 12 parts; sodium chloride, 19 parts; potassium chloride, 14 parts. Bath replenished by aluminium chloride only. E. M. F., 4 to 10 volts.

527,848, October 23, 1894, F. A. Gooch, New Haven, and Leonard Waldo, Bridgeport, Conn.

Removes chlorin and fluorin by adding water, as in 527,847, employing the same apparatus. May substitute water-gas for steam. The preferred bath is: Cryolite, 55 parts; aluminium chloride, 12 parts; magnesium chloride, 5 parts; sodium chloride, 28 parts. Replenishes with aluminium chloride only. E. M. F., 4 to 10 volts.

527,849, October 23, 1894, F. A. Gooch, New Haven, and Leonard Waldo, Bridgeport, Conn.

Similar to the preceding patents, but removes the chlorin or fluorin as acid gases by adding, from time to time, hydrated oxalic acid or other compounds containing either water of crystallization or of constitution or both. Baths: (1) Aluminium sodium chloride, 15 parts; cryolite, 55 parts; sodium chloride, 30 parts; or (2) Cryolite, 55 parts; aluminium chloride, 12 parts; sodium chloride, 19 parts; potassium chloride, 14 parts. E. M. F., 4 to 10 volts. The oxalic acid tends to oxidize carbon anodes.

527,850, October 23, 1894, F. A. Gooch, New Haven, and Leonard Waldo, Bridgeport, Conn.

Same as 527,849, except the bath, which is: Cryolite, 55 parts; aluminium chloride, 12 parts; magnesium chloride, 5 parts; sodium chloride, 28 parts. Bath replenished with aluminium chloride only. E. M. F., 4 to 10 volts.

527,851, October 23, 1894, F. A. Gooch, New Haven, and Leonard Waldo, Bridgeport, Conn.

Like the preceding, but removes the chlorin or fluorin and replenishes the bath by adding, from time to time, hydrous aluminium chloride. Bath: (1) Aluminium sodium chloride, 15 parts; cryolite, 55 parts; sodium chloride, 30 parts; or (2) Cryolite, 55 parts; aluminium chloride, 12 parts; sodium chloride, 19 parts; potassium chloride, 14 parts. E. M. F., 4 to 10 volts. Carbon anodes are somewhat oxidized.

528,365, October 30, 1894, F. A. Gooch, New Haven, and Leonard Waldo, Bridgeport, Conn.

Same as 527,846, except baths, which are: (1) Aluminium sodium chloride, 15 parts; cryolite, 55 parts; sodium chloride, 30 parts: or (2) Cryolite, 55 parts; aluminium chloride, 12 parts; sodium chloride, 19 parts; potassium chloride, 14 parts.

562,785, June 23, 1896, Heinrich F. D. Schwahn, Kansas City, Mo.

Mixes aluminious minerals purified by the process of his patent 514,039, with nitric, hydrochloric and sulphuric acids, and alkaline earth salts and oxides, *e. g.*, earths and barium sulphate, magnesium or calcium carbonate or dolomite, calcium hydrate or calcium or magnesium chloride. Adds sodium chloride or fluoride or cryolite, and sawdust or carbon. Heats to a glow, powders, mixes with carbon, preferably charcoal, places in an iron crucible and passes electricity through the mass. The mixture may be roasted in a combustion furnace before effecting reduction by the electric current. The apparatus employed is a horizontal, revoluble muffle of iron, surrounded by a heating jacket which is surrounded by an air jacket. The iron muffle serves as one electrode, two carbon rods of opposite polarity to the vessel passing through its side. The current employed is from 3500 to 5000 amperes, at 35 to 50 volts.

578,633, March 9, 1897, Frank A. Gooch, New Haven, Conn.

Electrolyzes a fused bath of: (1) Sodium chloride, 100 parts; hydrated aluminium chloride, 125 parts; and alumina, 8 parts: or (2) Sodium fluoride, 10 parts and hydrated aluminium chloride, 200 parts. The excess of aluminium chloride is decomposed by the heat of the bath into alumina, water and hydrochloric acid. The bath is replenished by alumina. E. M. F., 4 to 10 volts.

605,380, June 7, 1898, Henry S. Blackmore, Mount Vernon, N. Y.

Melts equal parts of sodium and potassium sulphides; adds sodium and potassium thiocarbonates; and finally adds alumina, which reacts to give aluminium sulphide which melts and becomes part of the bath. Electrolyzes with carbon anodes, the aluminium depositing at the cathode and the sulphur combining with the carbon anode to give carbon disulphide, which combines with the alkali sulphides present to reproduce the thiocarbonates. May produce the thiocarbonates for the initial bath by introducing carbon disulphide into the bath or producing it therein by the action of introduced sulphur on the carbon anodes. The reactions, involving the production of carbonyl sulphide, are illustrated by equations.

631,253. August 15, 1899. F. A. Gooch, New Haven, Conn.

Melts together an aluminium compound and a haloid of a metal more positive toward sulphur than aluminium. Adds a sulphur compound and alumina and electrolyzes. Specifically: Dissolves alumina in a fused bath of sodium fluoride, three parts, and aluminium chloride, two parts; covers the bath with powdered carbon; injects carbon disulphide or hydrogen sulphide, converting the alumina into aluminium sulphide, and electrolyzes with a current of sufficient voltage to overcome the resistance, plus 0.9 volts. May produce carbon disulphide in a bath covered with charcoal by introducing sulphur. May use an initial bath of aluminium fluoride and sodium fluoride. The apparatus comprises an iron cathode vessel lined on the bottom and half-way up the sides with carbon, the remainder of the vessel and anode openings in the sides being lined with "compacted" alumina. Carbon tubes passing through the side openings serve as anodes and inlets for the carbon disulphide. An iron bell lined with carbon depends into the bath to carry aff the gases.

673,364. April 30, 1901, William Hoopes, New Kensington, Pa.

Purifies aluminium from silicon, iron, copper, magnesium, calcium, sodium and potassium, by passing a current from an anode of the molten impure metal through a fused bath of cryolite, the silicon, iron and copper remaining undissolved on account of their lower affinity for fluorine than aluminium, while the other impurities dissolve with the aluminium, but are not redeposited with it, on account of their lower affinity for fluorine. The bath may contain alumina and may consist of chlorides of aluminium and any metal more positive than aluminium. The apparatus comprises a carbon-lined cathode vessel, in which is suspended a carbon anode tray containing the impure, molten aluminium, and having a terminal covered by a carbon tube. A current having a density of 20 to 30 amperes per square inch of the aluminium anode surface, is employed.

Electrochemical Industry

VOL. II. NEW YORK, JULY 1, 1904. NO. 7.

Electrochemical Industry

Published on the first of each month by the
ELECTROCHEMICAL PUBLISHING COMPANY,

[*Incorporated.*]
114-118 LIBERTY STREET, NEW YORK.

J. W. RICHARDS, PH. D. .....*President.*
E. F. ROEBER, PH. D. .....*Editor.*

Telephone Call: 7607 Cortlandt.

Subscription Price: $2 per year, postpaid to any part of the world. Single copies 25 cents.

ADVERTISING RATES GIVEN ON APPLICATION.

Copyrighted, 1904, by the Electrochemical Publishing Co.

Entered as Second-Class Matter, June, 1903, at the Post-Office at New York, N. Y., under the Act of Congress, March 3, 1879.

CONTENTS.

Editorial 255
International Electrical Congress..... 258
Notes on Platinum and its Deterioration. By William Campbell.... 259
The Electrolytic Process of Refining Gold Alloys. By Emil Wohlwill. 261
The Electrochemical Laboratory of the Massachusetts Institute of Technology. By H. M. Goodwin..... 264
Dimensions of the Films on Aluminium Anodes. By William Roy Mott 268
A Contribution to the Theory of the Jungner-Edison Accumulator with Constant Electrolyte. By M. U. Schoop..... 272
German Bunsen Society. By H. Danneel..... 276
Adaptability of Artificial Graphite Articles. By C. L. Collins, 2d.. 277
Electrometallurgy of Iron and Steel..... 280
Meeting of the Faraday Society..... 281
Analysis of Current Electrochemical Patents. By G. P. Scholl..... 282
Synopsis of Articles in Other Journals..... 286
Recent Metallurgical Patents..... 290
Correspondence: The Chemical Engineer. By W. Murray Sanders. 291
Current Notes..... 292
Book Reviews..... 293
Electrolytic Production of Hydrogen..... 293
St. Louis Exposition..... 294
A Deoxidizer for the Use of Steel Manufacture and Founders..... 295
Personal 295
Industrial Notes..... 295
Digest of U. S. Patents Prior to July, 1902. By Byrnes & Townsend. (Production of Sodium from Molten Electrolytes.).... 296

CONCENTRATION CHANGES IN THE LEAD CELL AND IN THE OXYGEN-LIFT CELL.

In this issue we publish the first part of an article by Mr. M. U. Schoop, giving an account of an able and interesting experimental investigation of the concentration changes and diffusion phenomena in the alkaline accumulator with constant electrolyte or "oxygen-lift cell," as christened by Dr. A. E. Kennelly. Mr. Schoop's method is very simple in principle, and extremely pretty. It consists essentially in suspending the accumulator electrode to be tested on the beam of a balance and observing its changes of weight while current is flowing and after it is interrupted. If we know exactly the chemical reaction which takes place in the active material of the plates, we can easily calculate the change of weight of the active materials themselves during the passage of a certain number of ampere-hours. This calculated value will generally differ from the change of weight found experimentally by Mr. Schoop's method, for the following reasons. First, there will be in general a change of the volume and the concentration of the solution in the pores of the plate, while current is passing; secondly, the weight of the electrode in solution equals its weight in air minus the weight of the displaced solution; hence, if the concentration of the outside solution changes, or if the accumulator plate undergoes a contraction or expansion, it will manifest itself in the weighings by Mr. Schoop's method. By varying the conditions of the experiment, it is possible to analyze the different effects which cause the change of weight found by this method.

Mr. Schoop has formerly applied this method to a study of the concentration changes in the pores of the lead accumulator. In this case the concentration changes are of utmost importance. It is well known that the e. m. f. of a lead cell depends on the concentration of the acid, and if a lead cell is discharged, the formation of sulphate at both plates necessarily causes a decrease of the concentration of the acid and therefore a decrease of the e. m. f. of the cell. If the discharge is made at a very low rate, diffusion and convection will have time to annihilate any concentration differences between the solution in the pores and outside so that the concentration in the acid of the pores of the plates is essentially the same as the concentration of the outside acid between the two plates. Since we have a decrease of this total concentration proportional to the ampere-hours given out by the cell, the e. m. f. will decrease correspondingly and gradually. If, however, a lead cell is discharged at a high rate, diffusion and convection will have no time to annihilate concentration changes between the acid in the pores and the outside acid, and the concentration of the

acid in the pores will be much lower than the concentration of the outside acid. Since the seat of the e. m. f. is essentially at the contact of the active material with the liquid (that is, the liquid in the pores), the accumulator will behave practically at any moment as though the whole cell contained solution of the concentration existing in the pores of the plates. Since the latter is very low with high discharge rates, the e. m. f. will be much lower than corresponds to the concentration of the outside acid between the two plates. This is the reason of the relatively excessive voltage drop which occurs in every lead cell at high discharge rates, and that this is the only essential reason, has been conclusively proven in several ways, especially by the extended researches of Dr. F. Dolezalek. This also gives the explanation of the fact that a lead cell having been discharged at a high rate, and having undergone a considerable voltage drop will increase again in e. m. f. after the circuit is broken; for now diffusion and convection will carry the more concentrated outside acid into the pores of the plates and the e. m. f. will therefore rise until all concentration differences in the cell are annihilated. This proves that in the lead accumulator the excessive voltage drop, observed with a high discharge rate, is a necessary consequence of the electrochemical reaction which goes on during discharge. The only means by which it would be possible to diminish this voltage drop would be to increase the porosity of the active material; but there is a limit to any such attempt, since it is necessary to keep the plates in a strong condition.

Mr. Schoop has now applied his method of weighing to the study of the concentration changes in the alkaline accumulator with constant electrolyte. Mr. Schoop is particularly fitted for this investigation, not only on account of his former work with the lead cell, but for the reason that he is now developing for a German storage battery company the nickel-iron accumulator of Dr. W. Jungner who has been working along the lines of the oxygen-lift cell, independently of Mr. Edison. A study of the concentration changes is well suitable to emphasize and explain one special advantage which the Edison accumulator has over the lead cell, namely, that it is far more able to be discharged at a high rate without loss of capacity than the lead cell. We have discussed above what happens in the lead cell at a high discharge rate. What happens in the Edison cell is entirely different. The principal result of the reaction is here a transport of oxygen from one plate to the other, while the solution and its concentration between the two plates remain unchanged. There are, however, variations of concentration in the pores of the two plates, the concentration increasing in the one plate and correspondingly decreasing in the other plate. This follows from theoretical considerations and has been proven to be correct by Mr. Schoop's experiments. It also follows from theoretical considerations that the change of e. m. f., due to the increase of the concentration in the one plate and the decrease of the concentration in the other plate, will be relatively small if these changes of concentration are not very great; certainly the variation of e. m. f. due to this cause is smaller than the variation of the e. m. f. in the lead cell. For this reason, a study of the concentration changes of the Edison accumulator would appear to be more of theoretical interest than of practical value, but as will be seen, Mr. Schoop's method enables him to use his experiments for drawing conclusions of practical importance.

Since the concentration of the KOH solution between the two plates does not change during discharge, the changes of weight of the plate which are observed by weighing the plate in the solution, can be due to the following three causes only. First, the weight of the solid active material changes on account of the oxidation of the one plate, and the reduction of the other; this change of weight can be easily calculated under the supposition that the cell is really an oxygen-lift cell. Secondly, there may be a contraction or expansion of the electrode plates; any contraction will manifest itself by an increase of weight of the plate in the solution since now a smaller volume of solution is displaced than before. Thirdly, there is a change of the concentration of the solution in the pores. This latter change of concentration can be rendered negligible by discharging the cell at a very low rate, so that the diffusion and convection have time to counteract all concentration changes. In this case, therefore, any excess of the increase of weight which may be observed beyond that accounted for by oxidation must be attributed to a contraction of the plate. In this way Mr. Schoop is enabled to study the change of the dimensions of the plate during discharge. If, however, a cell is discharged at a high rate, concentration changes will develop and will manifest themselves in a weight curve differing from that for slow discharges. That, indeed, this difference is due to the concentration changes, can be shown by observing the change of weight after the current is interrupted. Then the concentration changes will be gradually annihilated and any change of weight after interruption of the current must be attributed to this fact. The curves given by Mr. Schoop on these points are very interesting.

A study of the contraction and expansion of the electrodes of the Edison battery should give results of practical importance. We know that the concentration changes have not such an important influence on the e. m. f. curve as in the lead cell and a great part of the voltage drop observed in the Edison battery must therefore be attributed to an increase of internal resistance. This increase of internal resistance must be found inside the active materials of the plates. These active materials are contained in little perforated boxes, and when a discharge begins the layer of the active material next to the walls of the box will first be oxidized or reduced, since it is next to the outside liquid. When the discharge continues the places of oxidation and reduction will be gradually removed inwards towards the center of the boxes. The current then has to pass from the outside solution through the perforations in the boxes, through the liquid in the pores to those particles of active material in the center which are to be oxidized or reduced at that moment. From these particles, the current then must go back again to the metallic walls of the boxes, since the latter are connected to the terminals of the cell. The change of internal resistance in the plates of the Edison accumulator will, therefore, be partly due to a change of the resistance of the liquid in the pores (due to the change of its configuration and its

concentration) and partly to a change of the resistance of the solid particles through which the current passes from the places of oxidation and reduction to the outside walls of the boxes. These solid particles are a mixture of the active iron or nickel materials with some material of high conductivity, like graphite. For this reason the addition of graphite or the like to the active materials and the pressure under which they exist are of great importance for the internal resistance, and therefore for the whole behavior of the Edison cell. In looking over Mr. Edison's patents, one will find that Mr. Edison early recognized the importance of these facts and studied the best conditions of preparing this mixture very thoroughly and extensively. Now, of course, any expansion or contraction of the plates will have a great influence on their internal resistance, and for this reason the application of Mr. Schoop's method should lead to results of practical importance.

MOVING ELECTRODES.

While there is nothing novel in the method of changing the position of an electrode in electrolytic as well as electric furnace work for the purpose of regulating the current during operation, yet the gradual raising of an electrode has recently been made use of for a new and peculiar purpose, namely, for building up the product of an electrochemical reaction in a certain desired shape. In this issue we publish some information on two processes of this kind. Prof. Elihu Thomson has patented such a method for making hollow silica tubes in what is essentially a miniature electric arc furnace. He places pulverized quartz around two vertical carbon rods of suitable cross-section which form the electrodes, and by slowly raising the upper electrode, he draws a gradually lengthening arc and thereby produces a progressive fusion of the layer of quartz next to the electrode surface. In a German Bunsen Society paper Dr. Rathenau describes a method of making calcium sticks or rods by raising the cathode gradually during electrolysis in such a way that the calcium deposited at the end of the cathode always remains just in contact with the fused bath.

ELECTROMETALLURGY OF IRON AND STEEL.

In this issue we publish an abstract of the very interesting report made by the commission which was appointed by the Canadian Government to study the more prominent electric iron and steel furnace processes in Europe. The report contains some very interesting details concerning the plants visited by the commission, but its chief interest should lie in the very favorable conclusion reached by the commission on the possibilities of electric furnace processes in the reduction of iron ores. The cost given for the Keller process is surprisingly small; however, in this estimate the cost of one electric horsepower-year is taken at $10.00, which is an extremely low figure. Moreover it is well to keep in mind that the conclusions reached by the commission refer to the industrial conditions of Canada and that the local conditions in Canada, where good iron ores and water powers are plentiful and fuel is scarce, are much more favorable to electric iron and steel processes than for instance, in the Pittsburg district. Nevertheless, the metallurgical world will certainly watch with the greatest interest the developments in Canada.

In connection with this matter, it may not be out of place to refer briefly to the various ways in which electrical energy may be utilized in the iron and steel industries, besides the application for power purposes. In speaking of electric iron and steel processes, most people think only of the reduction of iron ores. True, this is the biggest problem, and various attempts have been made to solve it on a somewhat large experimental scale, although no process of this kind has yet proven successful on a commercial stage. The developments in Canada give new interest to this problem. But there are many other smaller, yet important problems, in which the iron and steel metallurgist could make use of the electric current which is now already available in every modern plant for lighting and power. The use of electric current for magnetic separation of lean ores is well known; electrostatic separation is being tried. The electrolytic refining process of Messrs. Burgess and Hambuechen enables us to get really pure iron if we want it. Mr. Edison is able to make seamless steel containers for his storage battery by electrolytic deposition.

On the other hand, electric furnace processes are in use on a commercial scale at various places for making ferro-alloys; if the starting material is a mixture of scrap iron with the oxides of the elements to be alloyed, like titanium, silicon, etc., the electric furnace has proven superior to the old methods, since it easily gives the extremely high temperature required for the reduction. For the preparation of special steels, various electric furnace processes have proven extremely useful on account of the ease of control, the cleanliness of operation and the absolute freedom from fuel gases. The only problem to be solved here by the electrometallurgical designer is to prevent any impurities coming into the fused metal bath from the electrodes, if electrodes are used. We have repeatedly referred to the ingenious methods by which this problem has been solved in different ways by Messrs. Kjellin, Heroult and Gin. First-class steels are now made in electric refining furnaces on a commercial scale, and they are able to compete successfully with the best grades of crucible steel. As Mr. Bennie remarked in a recent paper before the Foundrymen's Association, electrometallurgists are undoubtedly hitting the older art at the weakest spot when attacking it from the crucible steel standpoint. Finally, it may be found quite practical to use electric furnace methods in connection with our ordinary non-electrical metallurgical furnaces for special purposes, if a high heat is required at a certain moment and at a certain point. To such purposes the electric method is admirably adapted. Thus the suggestion was made by Dr. Richards in his recent presidential address to the American Electrochemical Society that it is a distinct commercial possibility to use electric heating to take off the peak of the load in our open-hearth steel furnaces, *i. e.*, to furnish electrically the last few hundred degrees of necessary temperature, while the combustion of gas furnishes the lower range. Mr. C. P. E. Schneider's patent, abstracted in this issue, is also quite suggestive in connection with this problem. It will thus be seen that the prospects of electric furnace methods in the iron and steel industries are very good in a great many different directions. But future advances will essentially rest on the judicious use of the principles of electric heating, *i. e.*, on furnace design, based on exact scientific principles and on experience.

INTERNATIONAL ELECTRICAL CONGRESS.

We are informed that the acceptances of membership in the International Electrical Congress of September 12-17, in St. Louis, number 1762, and that over 160 specially invited papers are promised, in all. One thousand certificates of membership have been issued to those who have become members by sending in their subscription, and about 100 more certificates are about to be issued.

Efforts are being made to secure the manuscripts of as many of the 160 papers as possible, by the first of July, in order to have them printed in advance and distributed among the Congress members at St. Louis. Thus far, six papers have been delivered, and many more are promised by that date.

The programmes scheduled for Sections D and E are here given. The similar programmes of Sections A, B and C have already been published in our June issue, page 214..

All communications concerning the congress should be addressed to the General Secretary, Dr. A. E. Kennelly, Harvard University, Cambridge, Mass.

Section D.—Electric Power Transmission

The chairman of the section is Mr. Charles F. Scott; the secretary, Dr. Louis Bell. The following papers have been promised:

E. Bignami, "Electrical Transmission Plants in Switzerland."

H. M. Hobart, "Conditions Conducive to Economy in Motor Design."

Maurice Leblanc, "Transmission of Alternating Currents Over Lines Possessing Capacity."

G. Mengarini, "Utilization of Hydraulic Powers in Italy."

F. G. Baum, "High-Potential Long-Distance Transmission and Control."

D. O. Blackwell, "The Tower-System of Line Construction."

H. W. Buck, "The Use of Aluminium as an Electrical Conductor."

V. G. Converse, "High-Tension Insulators."

M. H. Gerry, Jr., "Line Construction and Insulation for High Tensions."

L. M. Hancock, "Bay Counties Transmission System."

R. L. Hayward, "Some Practical Experiences in the Operation of Many Power Houses in Parallel."

J. F. Kelly and A. C. Bunker, "Long-Distance Power Transmission."

P. M. Lincoln, "Transmission and Distribution Problems Peculiar to the Single-Phase Railway System."

R. D. Mershon, "The Maximum Distance to Which Power can be Economically Transmitted."

P. N. Nunn, "Pioneer Work of the Telluride Power Company."

J. S. Peck, "The High-Tension Transformer in Long-Distance Power Transmission."

F. A. C. Perrine, "American Practice in High Tension."

C. P. Steinmetz, "Theory of Single-Phase Motors."

Section E.—Electric Light and Distribution.

The chairman of this section is Mr. J. W. Lieb, Jr., the secretary, Mr. Gano S. Dunn. The following papers have been promised:

André Blondel, "Impregnated Arc-Light Carbons."

Max Déri, "Single-Phase Motors."

E. de Fodor, "Rates for Electricity Supply."

E. Jona, "Insulating Materials in High-Tension Cables."

W. Kübler, "Upon Means for Compensating the Series-Connection of Induction Motors."

Karl Roderbourg, "Storage Batteries."

Guido Semenza, "Commercial Limits of Electric Transmission, with Special Reference to Lighting Service."

G. Stern, "The Superiority of the Alternating Current for Distribution in Large Cities."

W. Wedding, "Measurements of the Energy of Light and Heat Radiation from Electric Light Sources."

Arthur Wright, "Recent Improvements in Electrolytic Meters."

S. P. Thompson, Subject to be Announced.

B. H. Behrend, "The Testing of Alternating-Current Generators."

George Eastman, "Protection and Control of Large High-Tension Distribution Systems."

W. C. L. Eglin, "Rotary Converters and Motor Generators in Connection with the Transformation of High-Tension Alternating Current, to Low-Tension Street Current."

W. L. R. Emmet, "The Effect of Steam Turbines on Central Station Practice."

Louis A. Ferguson, "Underground Electrical Construction."

Gerhard Goettling, "Storage Batteries as an Adjunct to Central Station Equipment.

G. Ross Green, "American Meter Practice."

Caryl D. Haskins, "Metering Efficiency on Customers' Premises."

Francis Hodgkinson, "Steam Turbines."

John W. Howell, "Incandescent Lamps."

Philip Torchio, "Distributing Systems from the Standpoint of Theory and Practice."

W. F. White, "The Selection of a Distributing System for a Large City."

The following bodies have already promised to hold simultaneous conventions and joint sessions: The American Institute of Electrical Engineers, the American Electrochemical Society, the American Physical Society, the International Association of Municipal Electricians, the American Electrotherapeutic Association.

The following bodies have promised to send delegates to the Congress: The National Electric Light Association, The Association of Edison Illuminating Companies, the Société Internationale des Electriciens, Der Schweizerische Elektrotechnische Verein.

The delegates accredited to the Congress from various co-operating bodies are not expected to be called upon to vote upon any questions of international importance. All matters concerning units, standards, etc., will lie within the province of the Chamber of Government Delegates.

The delegates of the American Institute of Electrical Engineers and their papers to the Congress are as follows: Ralph D. Mershon, Section D., "The Maximum Distance to which Power can be Economically Transmitted;" M. I. Pupin, Section A., "Electrical Impulses and Multiple Oscillators;" C. P. Steinmetz, Section D., "The Theory of the Single-Phase Motor."

The delegates of the American Electrochemical Society and their papers to the Congress are as follows: W. D. Bancroft, Section C., "The Chemistry of Electroplating;" H. S. Carhart (with Dr. G. A. Hulett), Section C., "The Preparation of Materials for Standard Cells and their Construction;" L. Kahlenberg, Section C., "The Electrochemical Series of the Metals."

The delegates of the National Electric Light Association and their papers to the Congress are as follows: George Eastman, Section E., "Protection and Control of Large High-Tension Distributing Systems;" G. Ross Green, Section E., "American Meter Practice;" F. A. C. Perrine, Section D., "American Practice in High-Tension Line Construction and Operation."

The delegates of the Association of Edison Illuminating Companies and their papers to the Congress are as follows: W. C. L. Eglin, Section E., "Rotary Converters and Motor Generators in Connection with Transformation of High-Tension Alternating Current to Low-Tension Direct Current;" L. A. Ferguson, Section E., "Underground Electrical Construction;" Gerhard Goettling, Section E., "Storage Batteries as an Adjunct to Station Equipment."

SOME NOTES ON PLATINUM AND ITS DETERIORATION.

BY WILLIAM CAMPBELL, PH. D.

The great importance of platinum in the determination of high temperatures and other uses makes it one of the most interesting of metals. Its liability to deteriorate is well known to all, though the cause for such deterioration is not always apparent. The following notes on its crystalline structure, its occlusion of and permeation by gases, its behavior at high temperatures, etc., will therefore not be out of place.

CRYSTALLINE STRUCTURE.

When the surfaces of buttons of platinum are examined, large dendritic crystals are often seen. These dendrites consist of two axes at right-angles, which form the skeleton or framework of the grains or crystals, as in the case of most other metals. Andrews[1] has examined the microcrystalline structure of platinum. A small ingot was used and etching was performed by means of boiling aqua regia. Under a magnification of 360 diameters, primary and secondary crystals are seen (cp. those of lead, iron, etc.). The size of the primaries varied from 0.002 to 0.04 inch, and that of the secondaries from 0.0002 to 0.007 inch. Andrews states that the crystalline structure of platinum appears to generally resemble that of gold and silver. The effects of stress on platinum were also studied.[2] A cube of platinum 0.30 inch square was carefully polished and a force producing a compression of 10 per cent on the total height of the cube was applied. Upon examination it was found that innumerable fine "slip-bands" had been produced in many of the primary grains or crystals. As in the case of other metals it was found that stress alone, without etching, will often reveal the boundaries of the large grains or primary crystals. The finer "slip-bands" apparently show the crystalline slip which occurs along the facets of the smaller secondary grains.

DIFFUSION AND OCCLUSION OF GASES.

Sainte Claire-Deville and Troost discovered that hydrogen would pass through a plate of platinum prepared from the fused metal or through iron, at a red heat.[3] Graham's work along this line is well known.

The occlusion of oxygen and hydrogen by platinum black has been studied by Mond, Ramsay and Shields.[4] The results of Graham were confirmed by experiments with platinum sponge and foil. Platinum black, after drying at 100° C., is found to contain 0.5 per cent H_2O, which can be removed in a vacuum at 400° C., when platinum black is converted into a sponge. At any given temperature the water retained by platinum black is contstant. The density of platinum black, dried at 100° C., is 19.4, and allowing for water retained by it, is 21.5. Platinum black contains 100 volumes of oxygen, which begins to come off in quantity at 300° C. in vacuo, while the bulk has been given off at 400° C. A red heat is necessary for complete removal. Small quantities of CO extracted between 100° and 200° C.

About 310 volumes of hydrogen are absorbed, of which 200 volumes are converted into water and only 110 are really occluded. Part can be removed at normal temperature in vacuo, but the larger portion comes off at 250° to 300° C., while a red heat is necessary for complete removal. They conclude that there is not sufficient evidence for $Pt_{30}H_3$ and $Pt_{30}H_2$, and the arguments put forward by Berthelot are not justified. They consider that the heats of combination determined by Berthelot and Favre are valueless. The heat measured was due to the formation of water. In the case of Palladium[5], they find that there is no compound formed.

A. de Hemptinne, writing on the catalytic action of platinum black[6], describes the occlusion at very low temperatures. The absorption of hydrogen by carbon is mechanical, and at — 78° C. is far greater than at + 15°. In the case of platinum, however, the reverse holds good, and in all the experiments he finds the absorption to be greater the higher the temperature. If the absorption tube be allowed to return to the higher temperature slowly, at about — 40° C. a marked absorption of gas occurs. His experiments lead him to believe that a compound of hydrogen and platinum is indicated.

Harbeck and Lunge[7] have studied the action of carbonic oxide on platinum and palladium. They find that platinum black absorbs sixty times its volume of CO, while palladium absorbs thirty-six times its volume. A true chemical compound is probably formed, since the subsequent action of other gases, as hydrogen, does not eliminate the CO. It is very stable, but at 250° C. it suddenly decomposes into its constituents. As yet it has not been isolated.

The permeation of hot platinum by gases was observed by Randall[8], who found that hot platinum was permeated by hydrogen, but not so rapidly as Graham would lead one to believe. It is not permeated by either of the constituents of air nor by methane in spite of the latter's low density.

Winkelmann[9] points out that the rate of diffusion of hydrogen increases after the platinum has been heated for some time. This is due to the crystalline structure assumed by the metal and not to the expulsion of occluded air. He further states that the diffusion of hydrogen through red-hot platinum is not proportional to the pressure of the gas; it seems probable that the diffusion is accompanied by a dissociation of the molecules, and that only atoms of hydrogen pass through the metal.

PLATINUM ELECTRICAL-RESISTANCE PYROMETERS.[10]

Many years ago Matthiessen pointed out that the resistance of a wire of almost any pure metal increased nearly in proportion to the absolute temperature. Between 0° and 100° C. the increase in resistance of pure platinum wire is nearly 34 per cent, while at 1000° C. the resistance is approximately four times that at 0° C.

To Siemens is due the credit of working out the platinum resistance pyrometer in practical form and introducing it into use. The theory of the method and description of instruments for the measurement of temperatures up to 1000° C. were embodied in his Bakerian Lecture in 1871. In 1874 a report to the British Association condemned the method. This was based on experiments carried on in an ordinary open fire at about 800° C. The resistance was found to increase continuously with continued heating, and the wire to become rapidly deteriorated. There was a continuous change of zero. However, Callendar[11] showed that even at high temperatures the pyrometers could be made practically free from change of zero provided the wire was properly protected from strain and from contamination.

The sensitive part of the instrument is the coil of platinum wire, which is wound on a clay cylinder and placed in an iron tube about an inch in diameter and 5 feet or more long. Callendar examined an instrument (used at the Woolwich Arsenal) whose resistance had increased some 15 per cent. though never heated above 900° C. He found that the wire in places was brittle and stuck to the clay cylinder. He judged from the local nature of the action that the wire had been attacked by the clay or some impurity in it. He has found that mica is the best insulator, for it has no action on the wire, even at 1200° C. Platinum wire is readily attacked by metallic vapors. In the case of a pyrometer with copper electrodes which had been heated to about 850° C. for an hour in

[1] Proc. Royal Society, London, vol. 69, p. 433; Metallographist V, p. 233.
[2] Proc. Royal Society, London, vol. 70; Metallographist V, p. 236.
[3] Roberts-Austen: An Introduction to Metallurgy (1898), p. 54.
[4] Proc. Royal Society, London, 1895, 58, p. 242; 1897, 62, p. 50.
[5] Proc. Royal Soc., London, 1897, 62, p. 290.
[6] Zeits. Physikal Chem., 1898, 27, p. 429; Abst. J. Chem. Soc., London, 1899, II, p. 146.
[7] Zeits. Anorg. Chem., 1898, 16, p. 50; Abst. J. Chem. Soc., 1898, II, p. 166.
[8] Amer. Chem. Journal, 1897, 19, p. 682.
[9] Ann. Physik., 1902 [IV], 8, 388; Abst. J. Chem. Soc., 1902, II, p. 552.
[10] H. L. Callendar: Journal Iron and Steel Inst., 1892, I, p. 164.
[11] Phil. Trans. Royal Society, 1887, p. 161.

a porcelain tube, the marked discoloration of the mica near the copper leads showed that copper is appreciably volatile at that temperature. Owing to the action of the copper the resistance of the platinum coil showed an increase of nearly ½ per cent. For the above reason copper or silver leads ought not to be used for high temperature work. Again, solder of any kind cannot be used. Porcelain tubes will be found to give the best protection to the wire.

Thermo-Electric Pyrometers.[12]

Becquerel was the first to use the discovery of Seebeck to measure high temperatures, and he used a platinum palladium couple. Pouillet studied the method and compared an iron platinum couple with an air thermometer. Later Ed. Becquerel took up the study of the platinum palladium couple of his father, and was the first to see the necessity for using a high resistance galvanometer in order that the change in resistance of the couple on heating might be negligible when compared with the total resistance of the circuit. Regnault used and condemned Pouillet's couple on account of the irregularities he met with, but as he does not seem to have considered a high-resistance galvanometer necessary his experiments are hardly conclusive. Le Chatelier made a thorough investigation of the thermo-electric method about the same time as Barus[13], and we now have the thermo-electric pyrometer bearing his name. He found that iron, nickel, palladium and their alloys cannot be used for high temperature work, because they give rise to parasitic currents, which may sometimes be relatively intense when heated in certain of their points. Owing to the phenomena of hydrogenation the nature of palladium is completely changed and simple heating of an initially homogenous metal may cause the formation of couples. Platinum and its alloys with iridium and rhodium are free from these faults, and the irregularities previously observed are owing to the use of iron and palladium. A less important source of error is due to annealing, because, on heating a wire at a point between the hardened and the annealed part, a current is developed whose strength depends upon the kind of wire and the degree of hardness. All wires ought therefore to be carefully annealed. It is further pointed out that platinum and its alloys are liable to change, and on heating for a certain length of time, especially between the temperatures of 1000° and 1200° C. become brittle. This change is due to crystallization, and is more rapid in the platinum-iridium alloy than in that of platinum-rhodium, while in pure platinum the change takes place more slowly than in either. The greatest alteration is caused by a reducing atmosphere, and in a fire-clay furnace platinum wires are slowly destroyed.

Disintegration of the Platinum Metals in Different Gases

Holborn and Wien[14] in a comparison between the methods of measurements of high temperatures (electric-resistance and thermo-electric) soon found that above 1200° C. platinum begins to suffer from volatilization, which is strong enough to appreciably increase the resistance in the case of very fine wires. About 850° C. platinum is rapidly altered by hydrogen in the presence of siliceous material. In the case of one wire heated in an earthenware tube in an atmosphere of hydrogen, a brittleness was produced which may be accounted for by siliciuration of the platinum, because on heating a wire by the electric current inside a cold glass tube, even in hydrogen, no brittleness was obtained. In the case of palladium the resistance is increased some 60 per cent by the absorption of hydrogen at low temperatures, producing the hydride. If palladium is heated in an atmosphere of hydrogen in the presence of silicon, the same alteration as platinum is observed. The experiments with rhodium and iridium show that several heatings to a high temperature are necessary before they take

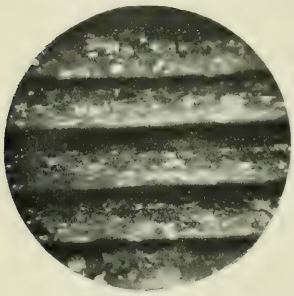


FIG. 1.—PLATINUM WIRE × 35.0.

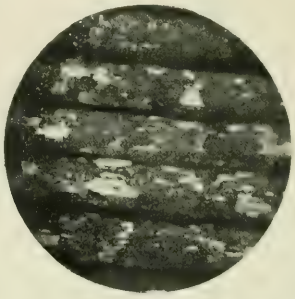


FIG. 2.—PLATINUM WIRE × 35.0.

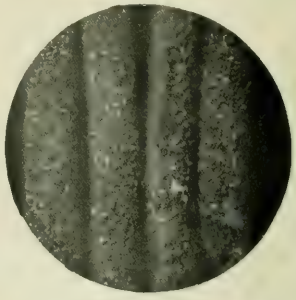


FIG. 3.—PLATINUM WIRE × 35.0.

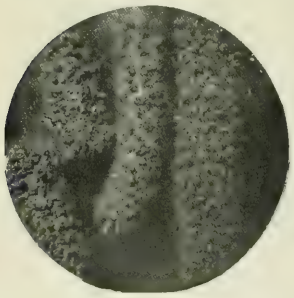


FIG. 4.—PLATINUM WIRE × 35.0.

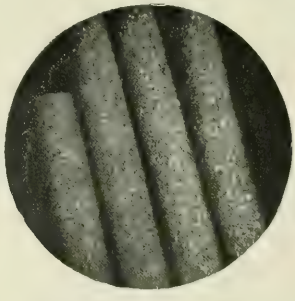


FIG. 5.—PLATINUM + 10 % Rh. WIRE × 35.0.

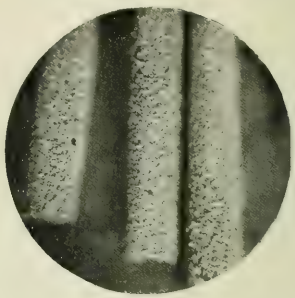


FIG. 6.—PLATINUM + 10% Rh. × 35.0.

[12] Le Chatelier and Boudouard: High Temp. Measurements.
[13] Bull. 54, 103, U. S. Geo. Survey, etc.

[14] Ann. der Phys. u. Chem., 47 (1892), p. 107; 56 (1895), p. 360. Review by R. Masse: Bull. de la Soc. d'Enc., fifth ser., I. (1896), p. 1012. See also "High Temperature Measurements."

their normal resistance. Holborn and Henning[15] found that when heated elctrically in air, the disintegration increased very rapidly with increasing temperatures. At 1670° C., platinum and rhodium showed about the same loss in weight, while iridium lost approximately ten times as much. There was no decrease in disintegration of the pure metals during the longest heating (3 hours), the loss being proportional to the time. In the case of the platinum-iridium alloys, however, changes were observed, produced no doubt by the more rapid disintegration of the iridium which caused a change of composition at the surface. Holborn and Austin[16] experimented with atmospheres of different gases and at different pressures. They found that the disintegration of platinum and rhodium was very similar. At atmospheric pressure, it is five times as great in oxygen as in air. In air at 25 mm. it is about ½ as much as at 760 mm. and in nitrogen it becomes very small. Iridium disintegrates ten times more rapidly in air than does platinum. At 25 mm. the loss is one-eighth that at 760 mm., and in oxygen the loss is eleven times as great. The phenomena are entirely different in the case of palladium. The disintegration in air increases with decreasing pressure, while the nature of the surrounding gas seemed to be without influence. When hydrogen was used, the palladium absorbed the gas and melting occurred before the temperature was reached where disintegration commences. When heated in a hydrogen vacuum, platinum and iridium showed no disintegration. Their paper is accompanied by a table of the results they obtained.

An example of the deterioration of a platinum/platinum 10 per cent rhodium thermo-couple was recently met with in some experiments on annealing of steel. The heatings were conducted in a cylindrical gas furnace, and were performed in from two to three hours. The bars of steel were packed in an iron tube with lime and asbestos, the thermo-couple being placed in the center. The wires were insulated by Morgan fire-clay tubes, surrounded by a larger porcelain tube, which, however, was open at both ends. On heating, it was noticed that a certain amount of steam issued at the beginning of the operation, which was later followed by gas leaving a black discoloration on the fire-clay tube projecting from the furnace. This gas undoubtedly arose from carbonaceous impurities in the asbestos used.

The thermo-couple did not show any deterioration or brittleness, and gave constant readings in calibration when used at medium temperatures, but above about 1050° C., it suddenly became brittle and showed a change when recalibrated, the deflections of the galvanometer giving a new, but similar curve. Under the microscope the change in structure was marked and was of two kinds. The one, evidently due to recrystallization alone, occurring within the fire-clay tubes, and the other, found in that part of the wires between the junctions of the fire-clay tubes, probably due to the evolution of gas giving rise to a rough incrusted surface to the wires. The effects were much more marked in the case of the platinum wire, while the platinum rhodium lead showed less change of structure, but was far more brittle.

Fig. 1, magnified thirty-five diameters, and obliquely illuminated, shows the structure of the platinum wire within the fire-clay tube. It is unetched, of course. Numerous large grains or crystals are seen to have grown in each of the five pieces of wire. Fig. 2, same magnification, shows even larger crystals which would well account for the brittleness of the wire.

Fig. 3 is a view of pieces of the platinum wire taken from near the ends of the fire-clay tubes, while in Fig. 4 are seen samples of the wire from between the tubes. The curious incrustation of metal almost completely hides the crystallization, and has caused a great thickening of the wire. It has been apparently caused by the evolution of gas from the metal, for it would seem to be too coarse to be due to volatilization of the metal alone.

Fig. 5 shows several pieces of the platinum-rhodium wire from within the fire-clay tube, but the structure is not nearly so coarse as in the case of the pure platinum. Fig. 6 shows three pieces of the platinum-rhodium wire occurring between the joints of the fire-clay tubes. The incrustation is well shown, but again the structure is not nearly so coarse as in the case of the pure metal. In similar heatings, made without the packing of lime and asbestos, no such marked deterioration of the couple was noticed. From the above will be seen the necessity of enclosing the thermo-couple in a porcelain tube, to which the products evolved during heating to 1000° C. and above cannot gain admission.

To sum up, the authorities seem to agree that platinum and its alloys are more or less volatile at high temperatures; that heating to temperatures above 1000° C. for any length of time causes brittleness. Whether this brittleness is due to crystallization alone, to the formation of compounds or to the absorption and evolution of gases, has not been definitely decided. It will probably be found that the first and last are the main causes and often occur together. It is, however, generally agreed that a reducing atmosphere in the presence of siliceous material causes the greatest alteration.

[15] Sitz. Ber. der Berl. Akad. (1902), p. 938.
[16] Phil. Mag., sixth series: No. 40, April, 1904, vol. 7, p. 388; also Sitz Ber. der Berl. Akad. p. 245 (1903).

THE ELECTROLYTIC PROCESS OF REFINING GOLD ALLOYS.

By EMIL WOHLWILL, PH. D.

In an article published in the June issue of this journal, I have discussed the electrolytic process of gold refining as a satisfactory method for winning pure gold, platinum and other platinum metals from a material which is itself the product of a previous parting operation. The application of the electrolytic process is, however, not necessarily restricted to such a supplementary second parting operation. For the essential characteristic feature of the electrolytic process is to dissolve electrochemically the constituents of a material, rich in gold, in a chloride solution and to deposit afterwards chemically pure gold from the electrolyte whatever the mixture of ions in the same may be.

The electrolytic process may, therefore, be applied to directly and primarily part gold alloys, if their composition is such that when used as anodes, the different components are continuously dissolved in the electrolyte; this means that either all constituents must be dissolved under the influence of the current or the formation of certain insoluble compounds must not cause any interruption in the solution of the other constituents, even at a high current density. Wherever these conditions are fulfilled, the electrolytic process of parting gold is able to compete with the methods which are generally used for parting gold containing silver. This does not mean that the electrolytic method can claim to replace these methods under all circumstances.

As to the most generally applied method of this kind—the parting process with the aid of sulphuric acid—it may be said that its most important peculiarity is its extraordinarily manifold applicability. It is essentially the same process by which, with the aid of sulphuric acid, the smallest quantities of gold are recovered from silver poor in gold, and by which mixtures of gold and silver in any proportion (after addition of silver) can be subjected to the parting operation. If it is of prime importance to treat very different materials by the same method, a satisfactory substitute will not be easily found for the method introduced by D'Arcet.

But this applicability to manifold purposes is not of decisive importance for industrial work. This is proven by the fact that for treating silver containing gold, the sulphuric acid process has been nearly completely replaced in the United States by the electrolytic process of parting, although the method introduced by Bernhard Moebius, is so far applicable

only for silver containing a low amount of gold and copper. The simple reason for the preference of the electrolytic method is that for parting the immense quantities of silver which contain a low proportion of gold, the manifold applicability of the sulphuric acid process is of no value, while the Moebius process has certain great advantages which the older method lacks.

The same may be said concerning the electrolytic treatment of gold containing silver, whenever the average composition of the same permits the direct application of electrolysis and the existing conditions offer difficulties for the operation of the sulphuric acid process. Such a difficulty is in many cases the requirement of keeping in store a greater stock of metallic silver which is not always available, and the necessity of continually recovering this silver as well as a part of the consumed acid; for this purpose much space is required with the usual method. In some districts it is especially the high price of the required large quantity of sulphuric acid which renders the application difficult for the gold producer. In more civilized districts and countries, the vapors of sulphuric acid and sulphurous acid which are developed in abundant quantities, and which are considered as a great nuisance by residents in the neighborhood, may cause the superintendent of the plant to look for a process which is less obnoxious to the neighborhood.

Moreover, the sulphuric acid process never yields a complete purification of the gold, and completely excludes the parting of platinum and if platinum is present in a large proportion, the process does not yield a complete recovery of silver. The process, therefore, requires in numerous cases the use of supplementary and even complicated operations, in order to yield a product which satisfies the practical requirements of purity.

The electrolytic process avoids all these difficulties and disadvantages. It permits the treatment of a given material without any supplementary methods, hence without complications. It requires small space. Of chemical reagents, only a minimum quantity is necessary. No obnoxious vapors are developed. The product of the main operation is always pure gold, even if very complicated mixtures are treated. There is no difficulty whatever, due to platinum and iridium being contained in the gold.

As we remarked before, these advantages of the electrolytic process can be utilized only if the anodic gold is of such composition that it does not contain too much of such constituents which can prevent the continuity of the dissolution of the anode. It should not contain especially too much silver and lead. It is therefore of importance to make it absolutely clear in which proportions these elements are permitted to exist in the gold anode. Dr. Tuttle states that in the United States Mint in Philadelphia, the application of the process is limited to bullion having a fineness of not less than 0.940 gold One might think that this figure represents the essential limitation of the process so that a content of more than 6 per cent of silver, plus lead, would make the application of the process impossible. This figure, however, does not represent the essential limitation of the process; it is rather a consequence of the peculiar modification in which the process is used, according to Dr. Tuttle, in Philadelphia. The feature of this modification is that the baths are heated to 50° or 55° C. only. If such a low temperature is used, the gold is obtained at the cathode in the condition described by Dr. Tuttle, *i. e.*, in spongy form, so that it must be pressed or melted in order to get perfect coherence. If at a temperature of 50° to 55° C. the current density is increased beyond a certain limit, the lack of coherence of the gold becomes worse; the danger arises that a part of the precipitated gold drops off and is mixed with the anode slime. For this purpose it is necessary to use a low current density.

If, however, the electrolyte is heated to 65° or 70° C., and the amount of gold contained in the electrolyte is sufficiently high, no soft or spongy gold is obtained, but the gold is perfectly solid. Without changing the surface of the cathode, it is possible to increase the strength of the current, and, therefore, to increase also the current density, up to the double of what is permitted at 50° to 55°, there being no danger whatever of any loss due to gold falling off.

Of equal importance is the increased temperature for the anodic reaction. The current density at which a development of gaseous chlorine starts at the anode (so that the dissolution of the anode plate is no longer complete) may be called the "density limit." Now experience shows that this density limit at the anode is the lower, the lower the temperature. The presence of a certain proportion of silver in the anode causes the latter to be covered with insoluble silver chloride, and this means a decrease of the active surface of the anode; if the current strength is maintained constant, the anodic current density is then increased. It will therefore be seen that the proportion of silver in the anode may be the greater the higher the density limit, and therefore the greater, the higher the temperature of the electrolyte.

Nevertheless, even at a temperature of 65° to 70° C., which I have given as the normal temperature of the electrolytic process in my patent specifications, the permitted proportion of silver in the anodic gold is relatively low as long as the employed current density is high, and as long as the operation is so conducted that the chloride of silver formed at the anode has so little adherence that it falls off, of its own accord, into the slime. However, even with a high current density the limitations of the process are very essentially reduced, if, with slight modifications of the apparatus and by following simple rules of precaution, the chloride of silver is scraped off from the anode plates at periodic intervals. In this way it is easy to recover directly as chemically pure gold the greatest part of the gold contained in alloys with 15 per cent of silver. It is evident that gold much richer n silver can be treated, if a stock of purer gold is available with which the alloy rich in silver can be blended so as to give an alloy containing 15 per cent of silver. In order to treat by electrolysis, for example, Klondike gold of the highest silver content given by Dr. Tuttle (0.219), it is only necessary to melt such gold with half the quantity of purer gold containing about 1 per cent of silver, as obtained from the slimes of the Moebius process or by refining with sulphuric acid. The limit of the content of silver given above is only a relative one; it relates to an operation in which it is important to recover within twenty-four hours the greatest part of the anodic gold. If this is not so important, it is possible to decrease the current with the same surface of the anodes and the proportion of silver in the gold may then be correspondingly greater.

I wish to remark that lead and bismuth contained in the anode are obnoxious to the electrolytic treatment, in so far as the allowable content of silver is reduced by about as many per cent as lead and bismuth are contained in the alloy.

If, as in the last cases, gold electrolysis is applied to alloys of gold with other metals, the continuation of the operation depends upon the requirement that gold, which has been dissolved chemically, is continuously added to the electrolyte. The reason for this is that by the electrolytic decomposition of the electrolyte, the quantity of gold deposited on the cathode corresponds to the ampere-hours passed through the electrolyte; on the other hand, the quantity of gold which is thus removed from the electrolyte is only partially replaced by the dissolution of gold from the anode, since the latter contains, besides gold, other constituents which are partly dissolved and partly changed into insoluble chlorides or sulphates. The electrolyte therefore tends to get poorer in gold and this will take place the more quickly the greater the difference between the amount of gold precipitated on the cathode and the amount of gold dissolved from the anode. The latter amount will be the smaller, the more other constituents of the anode are either dissolved or changed to insoluble chlorides in the same

time. To maintain the amount of gold in the electrolyte constant, it is necessary to add continuously new gold dissolved by a chemical operation. It is quite evident that it is advantageous to use, for this purpose, not pure gold, but the necessary amount of the same gold alloy which is under treatment. From this the advantage results that this portion is refined simultaneously with that serving as anode material. The complete content of gold of the alloy which is chemically dissolved will be precipitated by the electric current in the same chemical purity, and in the same coherent condition as the gold which passes into the solution from the anode.

There is also an economical advantage in this combination of the electric precipitation of gold which was chemically dissolved, together with the gold which had been dissolved by electrochemical action from the anode consisting of the same alloy; this advantage is that the precipitation does not require any chemical reagents, and only a small mount of electrical energy.

I will give a few figures to show the degree to which chemical work is required for this combination treatment. If a raw material is to be treated which consists of 85 per cent of gold and 15 per cent of silver, the rational operation of the process requires the chemical dissolution of 11.5 kg. of the same material for 100 kg. of gold deposited electrically; it is therefore necessary to dissolve one-tenth of the raw material in aqua regia. If, besides the 15 per cent of silver, the alloy also contains 2 per cent of copper, then the portion of the raw material to be chemically dissolved increases to 14.5 per cent; *i. e.*, one-seventh of the total quantity.

If the problem is to win by electrolysis pure gold from alloys of the composition of modern gold coins, which are a mixture of 90 per cent gold and 10 per cent copper, then it is necessary to dissolve 20 kg. of every hundred kg. of this alloy in aqua regia and add it to the electrolyte in order to maintain constant the original amount of gold in the solution during operation up to the finish.

I have given this calculation of the treatment of gold rich in copper only as an example. It may be permitted to add a few words concerning the practical operation of such a process. In such a case copper is dissolved from the anode, but is not precipitated from the electrolyte as long as there is sufficient gold in the electrolyte; it therefore accumulates in the solution. The same may be said concerning the copper originating from the gold which is dissolved chemically and added to the elctrolyte. If 100 kg. of gold containing 2 per cent of copper are treated, 2 kg. of copper will be contained in the electrolyte besides the gold; if 100 kg. of gold containing 10 per cent of copper are treated, 10 kg. of copper will be contained besides gold in the electrolyte at the end of the operation. Since copper is well soluble in the chloride solution, the accumulation of this metal may be pretty high before solid chloride is precipitated. The purity of the precipitated gold is not diminished by a very large amount of copper in the solution as long as the required absolute quantity of gold is present in the electrolyte. If, however, the same bath is used for continuously treating such alloys, the content of copper must gradually increase to an amount which requires the renewal of the bath. This will become necessary at a relatively early moment if the proportion of copper contained in the anode is high. But I do not think that one is justified to draw therefrom the conclusion which Dr. Tuttle draws —"that any considerable quantity of copper present in the bullion to be treated is undesirable."

The renewal of the solution means, of course, more work, and this means more expense, but the increase is not so great that it should render this operation undesirable. Let the limit of the content of copper in one of the cells, as used in Philadelphia, be 2 kg., then with an average content of 2 per cent of copper in the gold, 100 kg. of this gold-copper alloy could be treated in each cell before the limit of the amount of copper in the electrolyte is reached. This figure is changed to 50 kg. and 20 kg. if the content of gold in the alloy is 4 or 10 per cent, respectively. Therefore, according to the proportion of copper contained in the material, the cost of the renewal of one solution would have to be charged for treating 100, 50 or 20 kg., respectively, of the raw gold-copper alloy. This cost—exclusive of the value of the copper which could be easily recovered—is certainly not more than $1.00. Hence, the increase of work due to the accumulation of copper in the electrolyte is no sufficient reason for excluding gold, containing copper, from the electrolytic treatment.

After what I have said it might be advisable to modify to some extent the prognostication of Dr. Tuttle on the prospects of the electrolytic process in the industrial plants of the United States. Dr. Tuttle's remark that gold found in Europe is purer than American gold seems to be correct; for Russian gold, which is by far the largest part of European gold, contains in the average not more than 100 parts of silver. But it seems not correct to base on this fact the assumption that "the success of the electrolytic process will not be the same in the United States as in Europe." In the first line its success has not been very considerable in Europe. The application of the electrolytic gold refining process in Europe is so far limited to the three largest parting plants of Germany, mentioned in my former article. Russian gold would be without doubt perfectly suitable for the direct application of the electrolytic process, on account of its average composition, but it certainly is the very smallest part of all the various materials which the three German parting plants treat. Of these plants, the Norddeutsche Affinerie in Hamburg is—if I am not mistaken—the only one which uses on a larger scale the above-mentioned simple modification of the electrolytic process for the treatment of gold alloys containing a higher proportion of silver.

In Europe, it is not the lack of suitable material which has so far prevented the more extended introduction of the electrolytic methods, but probably the conservatism of the superintendents of plants who do not want to change methods which they have found useful in operation for many years, and who are not well acquainted with the advantages of the electrolytic process. It may be expected that in the United States it is also only necessary to overcome such conservatism in order to pave the path for the introduction of the electrolytic process of refining gold.

Dr. Tuttle doubts that it would be an advantage for the producers of gold in the United States to refine their products themselves by electrolysis, instead of selling it to the mint. He refers to the unavoidable loss of interest which would result from the electrolytic treatment for the producer, and which would be more than the small charge of the United States mint for the treatment. Indeed, in discussing the applicability of the electrolytic method, we would neglect an essential point if we would not take into consideration the question of interest. I will be as brief as possible concerning this point.

The question of interest is of different importance in the following two cases. In the first case, the problem is to use the electrolytic process in place of another one which also yields gold of so high a purity as necessary for practical use. The second and different problem is whether the introduction of the electrolytic process would be of advantage in a plant which has so far sold for cash gold which has not been refined or which has only been incompletely refined. In both cases interest is to be charged for the quantity of gold which must necessarily be contained in the solutions and in the form of rolled gold for cathodes. I find that for any thousand ounces of gold deposited during twenty-four hours by the current, 100 ounces of rolled gold are necessary for the cathodes. Since these are regained after twenty-four hours, the increase of cost per 1000 ounces of precipitated gold is 35 cents.

In about the same proportion gold must be contained in the

electrolyte. In order to calculate how much interest is to be charged for this gold in the solution, if 1000 ounces are to be deposited, we must take into consideration that the solution is generally kept in stock even if the electrolytic operation is interrupted for hours, days or even weeks. The figure which we want to get, is therefore obtained if the yearly interest for the total stock of solution is charged for the total yearly production of gold. The interest for gold in solution, as an item of cost of production, will therefore be smaller or larger, according to the degree in which the available plant is more or less rationally utilized. This is similar as with machines, etc.

Let us suppose that a plant is designed for depositing 3,000 ounces of gold per day, and let 240 ounces be the amount of gold stored in the solution. If this plant is utilized in such a way that the yearly production corresponds to the full work of 300 days, then the yearly interest for the 240 ounces of gold in the solution, charged to the full output of 900,000 ounces of gold, gives the interest of the gold in solution as 33 cents for every 1,000 ounces of deposit. This figure is to be doubled if the yearly output is only one-half. But with such an incomplete utilization of the plant, it would be desirable to precipitate temporarily the gold partly from the solution and to diminish in this way the loss of interest.

The superintendent of a plant, desiring to introduce the electrolytic process in place of another one, has to take into consideration, not only the interest for cathode gold and gold in solution, but also the interest for that part of pure gold which is obtained by electrolysis later than by the chemical process. On the other hand, the producer who is accustomed to sell impure gold for cash, has to take into consideration the total loss of interest caused by the delay in selling the product due to the refining process.

In order to get an exact estimate in this respect, it would not be fair to use the data which Dr. Tuttle has given for the work of the mint in Philadelphia, since it is evident that no special effort is made there to shorten the time during which the material is kept in the electrolytic cells. If my calculation is correct, at least ten days are required for complete consumption of the anodes, according to the practice in Philadelphia. It does not seem to me difficult to devise an industrial modification of the process by which, to a higher degree, the need of the producer is taken into account to reduce as much as possible the loss of interest. With respect to this need, the problem being to treat a given material in as short a time as possible, the thickness of the anode plates must be chosen as small as possible and as high a current density must be applied as possible. With respect to the latter point, the composition of the anode material represents certain limitations. For fine gold 15 amperes and more per square decimeter are well feasible; when the content of silver increases, the current density must be decreased, but even with a content of 10 per cent of silver, the operation is satisfactory with a current density of 9 amperes per square decimeter.

It is also necessary to take into consideration the structure of the material, in choosing the thickness of the anodes to be used at the permissible current density. For fine gold, containing platinum, plates of 4 millimeter thickness are suitable; with coarser gold it is preferable to use a thickness of 5 to 6 millimeters. Under all circumstances, the thickness of the plates and the current density can be so arranged that of the total content of gold in the anodes, 80 to 82 per cent are recovered after twenty-four hours in form of pure gold, in a condition ready for sale or shipment.

The producer who is accustomed to sell his impure gold to parting plants for cash, less the charges for refining, could sell twenty-four hours later 80 per cent of his gold at the full price without any deduction; of the remaining 18 to 20 per cent, 10 to 12 per cent are recovered during the second day and the balance completely on the third, if this portion of the material is used for supplementing the electrolyte, otherwise in decreasing portions during a few more days. Hence the delay in selling the product due to the electrolytic refining process causes a loss of interest, the main part of which is the one-day interest on the total anode material to which are to be added the one-day interest for 20 per cent of this quantity of gold and a smaller amount for the balance.

The figure for the total loss of interest will, therefore, not be too low, if it is assumed to be 1½ times the one-day interest of the total gold contained in the material to be refined in the cells. At the present price of gold, and charging 6 per cent interest, this amount would be less than $5.00 per thousand ounces of pure gold or less than $4.25 per thousand ounces of raw gold, containing 85 per cent of gold. The idea that this amount would render the electrolytic refining process impracticable for the American producer, would be justified only, if the charges of the American refineries were considerably below the self-cost of parting.

It is scarcely necessary to add that for refineries who subject the product of the sulphuric acid process or of the Moebius process to a second supplementary refining operation by means of aqua regia, the loss of interest due to the introduction of the electrolytic method of refining the gold would be reduced to one-third the amount given above.

THE ELECTROCHEMICAL LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

By Prof. H. M. Goodwin.

During the past year the Institute has equipped a special laboratory for instruction in electrochemistry to meet the demand which the many rapidly growing industries in this branch of applied science have created for men especially trained to undertake the class of problems arising in connection with the development of such industries. As frequent inquiries for a description of the arrangements and equipment of the laboratory have been received during the past winter, it is believed that it may be of some interest and value to those who may be contemplating a similar laboratory equipmen to describe briefly the essential features of the arrangements which have been worked out.

The electrochemical laboratory consists of two parts, one devoted to what may be called electrochemical measurements, and to processes requiring currents not greater than about fifteen amperes, and the oher to technical work requiring heavy direct or alternating currents up to several thousand amperes. In addition to these two principal rooms, six other special rooms equipped for measurements of electrical conductivity, dielectric constants, physico-chemical quantities, and for research, are provided. These contain no essentially novel features in their equipment, and require, therefore, no special description.

FIG. 1.—LABORATORY OF ELECTROCHEMICAL MEASUREMENTS.

A—Private Office.
B—Balance Room.
C—Hot Closet.
D—Group of four Students' Desks.
D'—Instructor's private Research Desk.
E—Three Hoods for Electrochemical analysis.
F—Electric Furnaces.
G—25-kw. Direct-Current Motor-Generator.
H—Hood.
I Instrument Case.
K—Set of ten large Storage Batteries and Switchboard.
L—18-inch Shelf.
M—Grinding and Polishing Machine.
N—2-hp. Power Motor.
O—50-kw. Transformer.
P—Slate-Top Masonry Pier.
R—Reagent Shelves.
S—Sink.
T Thermostat.
V—Steam Evaporating Cups.
W—Special Still for Conductivity Water.

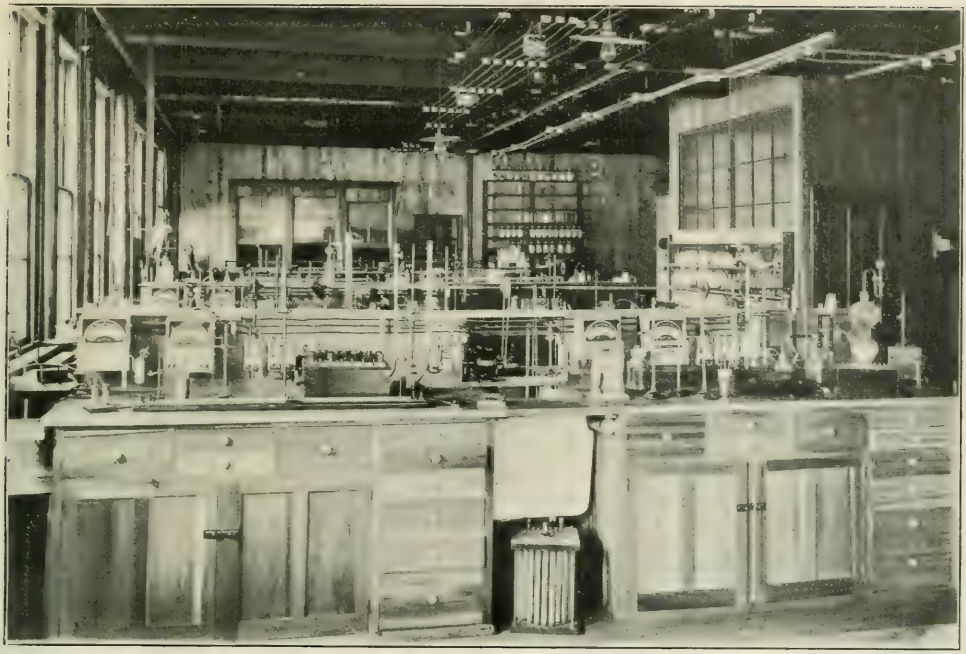


FIG. 2.—GENERAL VIEW OF LABORATORY, LOOKING NORTH, SHOWING ELECTROCHEMICAL EQUIPMENT PROVIDED WITH EACH DESK.

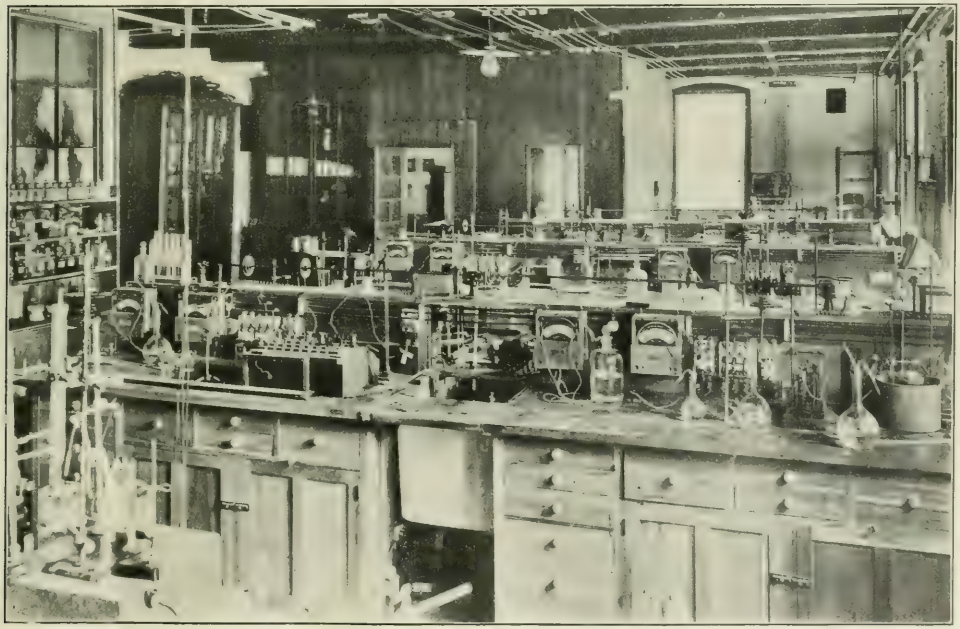


FIG. 3. GENERAL VIEW OF LABORATORY, LOOKING SOUTH, SHOWING ARRANGEMENT OF DESK CIRCUITS, ETC.

The laboratory of electrochemical measurements (30 x 62 feet), is equipped with desks for twelve students. The general arrangements are indicited in the accompanying plan, Fig. 1, Room I. The most important feature of the equipment in this laboratory is the arrangement of circuits and other conveniences on the desks. These are arranged in three groups of four each with a sink at each end and a large thermostat in the center. Each desk is provided with three faucets, including a Richards suction pump and gas at the sink end. Along the back of each desk is a switchboard, 14 inches high, to which the terminals of the various circuits are brought. Opposite switchboards are separated by a 4-inch space and bridged over the top by a shelf. This permits ample space at the back of each switchboard for the necessary wiring.

The circuits provided are four in number, 110 volts, 12½ volts, 25 volts, and 2 volts, respectively. The first is wired from one side of the general 220-volt direct-current power circuit of the building; the second and third constitute a three-wire system from a special motor generator located at G, Fig. 1; the 2-volt circuit is connected to a large storage cell, four of which, one for each desk, are set up between the desks and under the thermostat. The method of wiring is shown in Fig. 4.

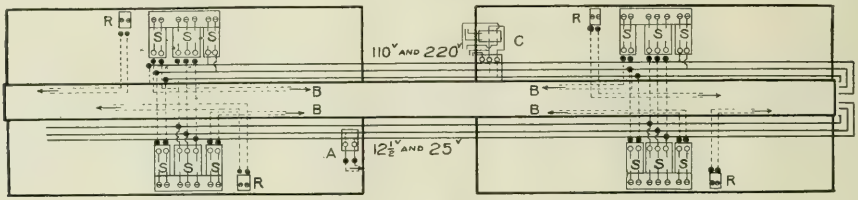


FIG. 4.—DIAGRAM OF WIRING OF DESK CIRCUITS.

A—12½-volt cut-out for charging accumulators for the desks.
B—2-volt circuit to accumulators.
C—Cut-out to circuits leading to 1/12-hp motor and to heating coils in thermostat.
R—Terminals of rheostat.
S—General Electric combination switch and cut-out.

The battery circuits are brought up back of the switchboards as indicated by the dotted lines B. The three-wire 12½ and 25-volt circuit is wired along the top of the switchboard on one side of the desks, and tapped off across to the opposite side as indicated. The three-wire 110-volt and 220-volt circuit is run in a similar manner along the top of the opposite switchboard, and 110 volts tapped off at each desk and across to the proper cut-out on the opposite desk. The circuits are brought out to General Electric porcelain combination switch and cut-outs, connected in turn to large double binding posts mounted on fiber. Each circuit is fused in general for 10 amperes. Currents of this magnitude may be taken from any circuit without affecting adjacent circuits. The fuse plugs in each circuit may be replaced by lamps of different resistances, a set of which permits a convenient and ready adjustment of current within wide limits. For a finer adjustment of current a large rheostat on the floor at the end of each desk, wired to terminals R, on the switchboard, is provided. For a still finer adjustment of resistance, such as is required in tapping off potentials in determining decomposition voltages, a German silver wire or coil with sliding contact is stretched between binding posts along the top of the switchboard. The electrical accessories of the desks are completed by portable Weston ammeters and voltmeters. The general arrangement may be seen in Fig. 3, which gives a general view of the laboratory looking south.

The porcelain lined thermostat, 36 x 18 x 20 inches, in the center of each group of four desks, is heated and regulated electrically. The outside is heavily lagged with magnesia to reduce radiation. To bring the temperature quickly up to any desired value, a heating coil of heavy German silver wire is switched onto the 110-volt circuit at C, Fig. 4. A constant temperature is then maintained by an ether regulator which operates a relay mounted at the left of the open space above the thermostat. As the temperature of the bath rises or falls above the desired temperature, the relay opens or closes a 110-volt circuit through a 32-c. p. lamp, the bulb of which is nearly completely immersed in the water of the thermostat. The heat thus generated is more than sufficient to compensate for the loss by radiation and evaporation, and has been found to work most satisfactorily. A small 110-volt 1-12 horse-power motor serves to drive in the thermostat a shaft with paddle wheels for stirring the water, and with a device for rotating bottles for saturating solutions. The motor is also belted up to a shaft which runs the whole length of the shelf at the top of the switchboard. The shaft carries four cones of pulleys, one for each desk, by means of which power is furnished to each student for stirring. A heavy brass rod carrying an adjustable arm with a horizontal cone of pulleys equal in size to those on the shaft, can be screwed, when desired, into a brass plate into the top of the desk.

The equipment of electrochemical apparatus provided with each desk is shown in Fig. 2. It consists of a silver, a copper, a gas and a titration voltameter, transference apparatus, complete conductivity apparatus with a resistance box and a slide wire bridge, a Lippmann electrometer, keys, commutators, a potential box and complete accessories for potential work, a three-scale, 3-volt, 15-volt, and 150-volt Weston voltmeter, and a Weston milli-voltmeter, with 15-ampere auxiliary shunt for use as ammeter. The advantage of giving each student a complete outfit at the start is evident: for first, it permits the whole class to work concurrently on the subjects which are being discussed in the lectures; second, it is conducive to great economy of time in the work of the student, and third, it greatly increases the interest and care with which the student undertakes the calibration and standardization of his instruments, if he feels his own responsibility for them throughout all his later work.

The laboratory is provided with a balance room, a hood, a drying closet, steam cups, distilled water, and a large still of special construction for the redistillation of pure water for conductivity work. Three hoods of special construction, each equipped with four different circuits of constant voltage connected with the large acumulators, and with means of regulating and varying their temperature, are provided for electrochemical analysis.

The laboratory for heavy current work, Room II. (30 x 32 feet), is equipped for the purpose of illustrating on a fairly large scale various electrochemical processes involving the use of both direct and alternating currents, and to provide facilities for research work along these lines.

Direct current is supplied from a Holtzer-Cabot motor generator of 25-kw. capacity, shown in Fig. 5. It is enclosed in a room with glass windows to protect it from dust and acid fumes. The motor is supplied with power from the electrical engineering power plant at 220 volts direct current. The double current generator is directly coupled to the motor and

delivers under full load 1000 amperes at 12½ volts at each commutator, which may be connected either in series or parallel as desired. The voltage may be varied at will by varying the resistance of the separately excited fields. The generator may be switched onto the three-wire system leading directly to

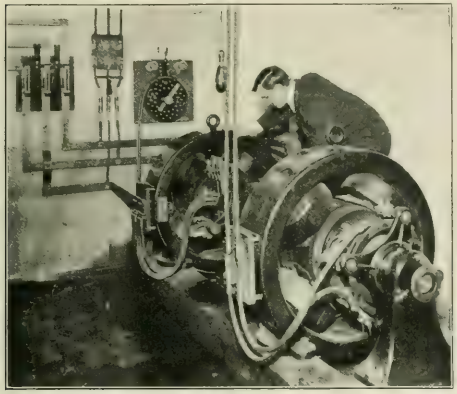


FIG. 5. 25-KILOWATT DOUBLE CURRENT MOTOR-GENERATOR FOR ELECTROLYTIC WORK.

the switchboard at the front of each desk as already described, or to heavy copper bus-bars 2 inches x ½ inch section and 32 feet in length which extend around two sides of the laboratory, 5 feet above the floor. Connection is made between the electric furnaces, which are arranged along the sides of the room and the bus-bars by means of heavy flexible cables which are easily clamped to the latter by heavy screws. The general arrangement is shown in Fig. 6.

For electrolytic work requiring very constant low voltage, and in particular for work which must proceed continuously over night, such as plating, electro-analysis and electro-depositions in general, a set of ten large chloride accumulators capable of furnishing 150 amperes each are provided. These are each connected to a switchboard by means of which any combination of the cells in series and parallel may be easily effected. Currents from 150 amperes at about 20 volts to 1500 amperes at 2 volts are thus available independent of the motor generator. The batteries are charged in series on the 25-volt circuit from the generator.

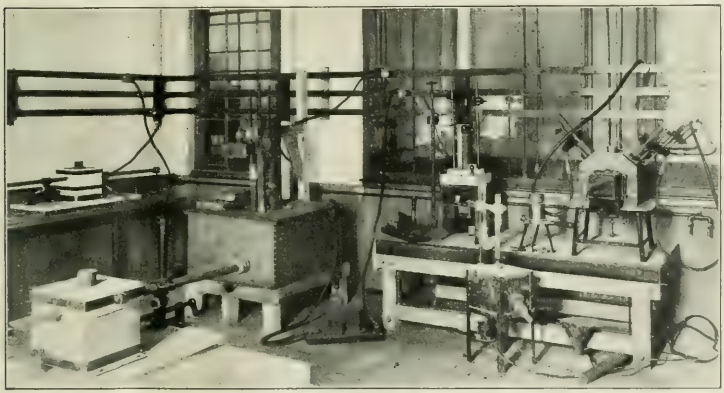


FIG. 6.—ARRANGEMENT OF BUS-BARS AND GROUP OF ELECTRIC FURNACES.

For furnace work requiring heat only, and for the purpose of bringing to a state of fusion electrolytes to be subsequently subjected to electrolysis, a 50-kw. transformer of special construction is provided. This is of the core type, and can be used on either a 2200 or 1100 volt circuit at 60 or 125 cycles, by connecting the primary windings in series or parallel. At present it is used on a 1100-volt circuit of 125 cycles. There are 16 independent secondaries so wound that each can deliver 300 amperes at 10 volts. The terminals of each of these are brought out to a switchboard where they can be thrown in multiple or series or used in independent combinations as desired. The two halves of the switchboard are quite independent, so that 25 kilowatts can be drawn simultaneously from each set of bus-bars at any voltage from 10 to 80 volts in steps of ten volts. By connecting the two halves in series or parallel, currents from 300 to 4800 amperes at pressure from 160 to 10 volts respectively can be obtained.

Flexible cables, each capable of carrying 500-700 amperes are used to connect the transformer with furnaces which

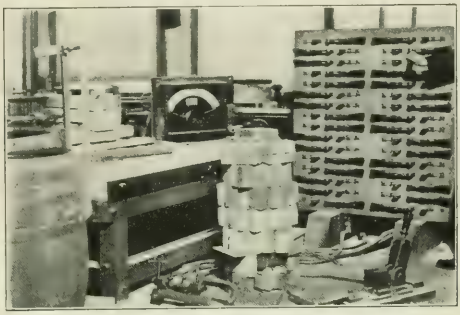


FIG. 7. 50-KW. TRANSFORMER SWITCHBOARD AND RESISTANCE FURNACE.

cannot be built or brought close to the transformer. Fig. 7 shows the transformer connected for a run on a resistance furnace used in an investigation now being carried out on the properties of refractory oxides. The laboratory is provided with all the necessary accessories to the above power equipment in the way of resistances, choke coils, and direct and alternating current measuring instruments for the measurement of current, voltage and power. The calibration of these instruments and of the student's own desk instruments form a part of the regular work which each student performs in the electrical standardizing laboratory. For measuring high temperatures, the laboratory is well provided with thermo-electric pyrometers. The calibration of these instruments forms a part of the regular work in the laboratory of heat measurements.

The laboratory is equipped with six different types of furnaces, including the Moissan and Borchers types, platinum and graphite resistance furnaces, and a large furnace especially constructed for aluminium reduction. As many furnaces have to be built up for each run, special tables have been designed for this purpose. These contain no

wood in their construction except the supports. The tops are concreate arches supported at the sides by iron I-beams. A layer of fire bricks is placed in sand on the cement, and on this foundation the furnaces are built. No danger from fire has been experienced thus far with tables of this construction.

Finally should be mentioned the typical electro-plating plant with tanks of various size up to 30 gallons capacity for illustrating nickel, copper, silver, gold and brass plating. This includes, of course, the necesary grinding, polishing and finishing accessories.

In concluding the above description of the laboratory which has been equipped to provide special facilities for instruction in electrochemistry, it may not be out of place to indicate the general plan of the course in electrochemistry as given at the Institute. The present four years' course was established by the faculty five years ago, and is given under the direction of the department of physics, that department having inaugurated special instruction in electrochemistry as early as 1894. The chief features of this course are a very thorough training in theoretical and applied electricity and chemistry, together with as much of the subjects of mechanical engineering and metallurgy as can be included in a course of four years' duration.

The work of the first year is common with that of all other engineering courses, and includes mathematics through analytic geometry, mechanical drawing and descriptive geometry, chemistry, language and general culture studies. The latter are continued in all courses, at the Institute throughout the first three years. Specialization begins in the second year in chemistry and electricity. The former consists of qualitative and quantitative analysis throughout the second year and first half of the third year, followed by organic chemistry, gas analysis and assaying in the second term of the third year. These courses all lead up to a very thorough course in industrial chemistry given throughout the fourth year.

Theoretical chemistry is begun in the second year and is continued to the end of the third year. This forms a very thorough preparation for the theoretical and applied electrochemistry, which constitutes a large part of the professional work of the fourth year.

The electrical studies are also arranged in a progressive sequence. Electricity is treated first in the course on general physics of the second year. Theoretical electricity is then begun in the second term of this year, and is continued through the third and fourth years, the later work being devoted to the subject of periodic currents and their applications to alternating currrent machinery. Parallel with this theoretical work courses are given in electrical measurements and testing, in electrical engineering and in the electrical engineering laboratory.

In addition to subjects included in the two lines of work described above, a certain number of engineering subjects are required. These include metal work, mechanical engineering drawing, mechanism, valve gears and thermodynamics, all leading up to a very practical course in the fourth year on general machinery, including engines, pumps, compressors, etc. Non-ferrous metallurgy, and work in the metallurgical laboratory comlete the group of subjects included.

In the last term of the course each student devotes a considerable portion of his time to the preparation of a thesis, embodying the results of an experimental research on some electrochemical subject.

Four years is admittedly too short a time to include in a course all subjects which an electrochemist is likely to find useful in the practice of his profession, and a fifth year, or a graduate course which can be arranged to great advantage, is highly recommended to those who find it practicable to devote another year to study before beginning professional work.

At its recent Commencement exercises the Stevens Institute of Technology conferred the degree of Doctor of Science to Mr. Edward Weston.

DIMENSIONS OF THE FILMS ON ALUMINIUM ANODES.

By William Roy Mott.

The corrosion of aluminium was shown in a previous paper[1] to be greatly hindered by a film which was better for this purpose, the higher the voltage of its formation. This indicates that the film is thicker the higher the voltage; so definite data upon the dimensions of the film become vital to a careful consideration of film formation at an aluminium anode, especially since the film constitutes the essential part of the aluminium electrolytic rectifier and condenser. The thickness of the di electric determines the capacity of the condenser. Since the thickness of the film varies greatly according to voltage and electrolyte, it is not surprising that the measurements of the capacity made by Franchetti, Nodon, Mitkiewicz and Zimmerman are widely at variance. Campbell and Gahl have also found that they did not get concordant results. Hence, the thickness of the film is of practical importance, as well as theoretical.

The thickness of the film is the object of investigation considered in this paper. The weight of the film and coulombs required for its formation is the first phase of the subject.

Anode Gains in Weight.

When weighed sheets of aluminium are used as anode in a saturated sodium acid phosphate solution it is well known that the aluminium tends to insulate itself. Even with a pressure of one hundred or more volts, very little current flows. That this is due to the aluminium and not to the resistance of the electrolyte may be proved by measuring the resistance of the electrolyte with lead plates and getting the *CR* line, and it is found that the *CR* drop is less than 1 per cent of the total drop. In forming these plates, considerable current flows at the start, but in a few minutes decreases very greatly. In four experiments (the results are given in Table I. and II.) the aluminium plates were weighed to a tenth of a milligram before and after and were found each time to gain in weight. At anodes the tendency of metals is to go into solution, hence the gain in weight of the anode does not come from a metal plating out of the solution. The question arose as to whether, at the contact of the solution with the air and the aluminium, there was any marked gain or loss. To find this out, the area of the exposed part was decreased by thirty times; the proportionate gain in weight was not appreciably affected. Plate II. was treated as anode and cathode several times, and then finally used as anode and found to have practically the same weight as when weighed as anode the first time. Plate III. was run as cathode for awhile (two minutes, 2.5 amperes). It was found to have lost two milligrams, which left two and two-tenths milligrams gain over the original weight.

The aluminium Plate II. was now run as anode and about twenty coulombs were required to re-form it. This is one-sixth the number of coulombs required for the original formation. (The starting current was about 5 amperes, which fell in ten seconds to 0.1 ampere). Now, leaving the plate an open circuit for ten minutes, it was observed on closing the circuit that about two coulombs were required for reformation. As nearly as I could estimate it, the starting current was 0.9 amperes, which fell to the normal leakage current in from one to two seconds. The weight was now found to be 7.8905 gs. or 0.1 milligram greater than at the last weighing, when it was the cathode. Aluminium Plate III. was, after having been formed as anode and properly washed and dried and weighed, left out of the solution for about an hour to find out how many coulombs would be required to reform it. On testing, the initial current was found to be small, and this decreased in a few seconds to the normal leakage current.

These experiments upon the four aluminium plates show that there is a real gain in weight of the anode due to the

---

[1] The Corrosion of Aluminium and its Prevention. Electrochemical Industry, April, 1904.

formation of the film which is fairly permanent. The disappearance of the resistance offered by an aluminium anode cannot be used as evidence (as Lecher and some others have done) that the film has been dissolved.

A fair criticism of these experiments would be that the actual weighings are greatly in error because of adhering moisture. In the case of weighing glass beakers, errors of consid-

TABLE I.

GAIN IN WEIGHT OF ALUMINIUM ANODE.*

Number of Plate.	I.	II.	III.	IV.
Thickness[1]	.0086	.0150	.0150	.0150
Area of plate[2] ..	145.	135.	140.	190.
Width[1]	14.5	13.5	14.	0.35
Weight before[3] .	4.7567	7.8865	8.7561	7.0995
Weight after[3] ..	4.7607	7.8924	8.7622	7.1085
Gain[3]	.0040	.0059	.0061	.0090
Gain per sq. dm.[3]	.0027	.0044	.0044	.0047
Gas at cathode[4]	12.	12.	10.	12.5
Coulombs[5]	130.	135.	120.	115.

[1] Centimeters. [2] Square centimeters. [3] Grams.
[4] Gas given off at cathode is measured in cubic centimeters. One cubic centimeter, by experiment at this temperature, corresponds to a passage of about ten coulombs.
[5] These coulombs were obtained by integrating the current-time curves for the formation of the film. (See Table II.).

* The plates were formed at 125 volts, direct current, in a saturated solution of disodium hydrogen phosphate and at room temperature.

TABLE II.

MODE OF FORMATION OF FILM.

Plate I.			Plate II.		
Time, Seconds.	Amperes.	Volts.	Time, Seconds.	Amperes.	Volts.
0	7.	50	0	7.	...
10	3.	70	10	2.	88
20	1.5	95	20	1.5	...
30	.9	...	30	.9	92
40	.5	...	40	.6	117
50	.3	...	50	.4	121
60	.3	...	60	.3	...
120	.1	125	120	.2	125
Plate III.			Plate IV.		
Time, Seconds.	Amperes.	Volts.	Time, Seconds.	Amperes.	Volts.
0	7.	33	0	5.	30
10	2.4	96	10	2.5	72
20	1.2	112	20	1.5	80
30	.6	120	30	.9	89
40	.4	124	40	.7	91
50	.2	124	50	.6	103
60	.1—½	124+	60	.3	114
120	.1	125	120	.2	125

erable magnitude may be made, due to this cause. For this reason, the author ran blank experiments, both upon the unformed and the formed aluminium plates. No variations greater than one-tenth milligram were observed. But the most conclusive proof of the permanence of the film in air was found in drying 39 milligrams of the detached film. The greatest extremes of drying conditions had an effect of less than 3 per cent.

The formation of the film is accompanied by more or less corrosion of the anode. This is an important factor. It seems to have been overlooked by Cook in some experiments on aluminium electrodes in sulphuric acid. His experiments do not justify his position that the film is an oxide. This point will be more fully considered later. This corrosion of the anode is usually small during the formation of the film, but nearly all the leakage current (the steady current) that flows after the film is formed is corroding. So all the results by this method give *minimum* values of the calculated thickness of the film.

Further experiments were made to determine the effect of the voltage upon the thickness of the film which was formed as rapidly as possible by the proper manipulation of the resistances in the circuit. The plates after being formed were dried and weighed. The weighings[1] were done by the method of swings. In the following experiment, the same plate was first formed at 20 volts, then at 40 volts and finally at 60 volts.

TABLE III.

ALUMINIUM PLATE FORMED IN SATURATED DISODIUM HYDROGEN PHOSPHATE.

Original weight (grams	3.94212
Formed at 20 volts	3.94516
" at 40 volts	3.95023
" at 60 volts	3.95041
Increment in weight at 20 volts.....	+.00304
" " at 40 volts.....	+.00507
" " at 60 volts.....	+.00018
Total gain in weight at 20 volts.....	.00304
" " at 40 volts.....	.00811
" " at 60 volts.....	.00829

Each time the plate was washed (in distilled water), dried and weighed. The results are given in the following table III. and are plotted on Fig. 1.

This series of experiments were made on plates of 100 sq. cm. area (an area of surface of 200 sq. cm.). The rate of

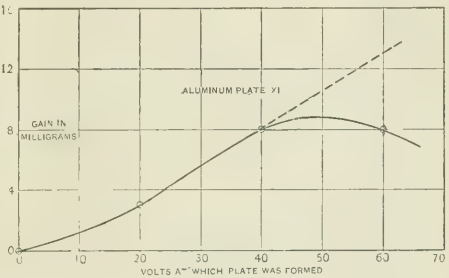


FIG. 1.—INFLUENCE OF VOLTAGE OF FORMATION UPON THE FILM.

corrosion at 60 volts appears to balance the rate of gain of the anode. This was duplicated with other similar experiments which it is not necessary to give here.

Calculation of gain in thickness of the aluminium plate, and calculation of the thickness of the film can now be made. Ordinary hammered aluminium has a specific gravity of 2.67. Bauxite has a specific gravity of 2.55. The aluminium hydrates have a specific gravity greater than 1.0. Assuming that one cubic centimeter of this film weighs two grams, then one milligram will occupy .0005 cubic centimeters; where we have both sides of a plate with an area of 100 sq. cm. on a side, the thickness of the film would be .0000025 cm. Factors of variation are, specific gravity of the film (between 1.0 and 2.5); the proportion of aluminium in the film which, of course, added nothing to the weight of the plates; and the actual loss of material by corrosion. The gain in thickness of the aluminium plate is not the sum of the thickness of the films on both sides, but only a fraction of this, inasmuch as some of the aluminium goes into the formation of the film.

If we assume that the film contains 40 per cent aluminium[2], then we must add 80 per cent to the observed gain in weight.

Calculated out on these assumptions, the thickness of the

[1] These weighings were made by Dr. Patten, for which I thank him for his kindness in doing this.
[2] A reasonable value, in view of the various chemical analyses that have been made of the film.

film formed on an aluminium anode in phosphate solutions is as follows:

Voltage.	Thickness.
20 volts.	.000014 centimeter.
40 "	.000037 "
60 "	.000038 "

At 60 volts, the film is really thicker than at 40 volts. In fact we may assume a rate of increase in weight of about 4 milligrams (for 100 sq. cm. of aluminium plate) for every rise of 20 volts, so at 100 volts we would expect a thickness of about .00010 cm. This would be in accord with the other data. The next consideration is the coulombs required for the formation of the film.

Coulombs to Form the Film.

The film forms to a certain thickness for each particular voltage, but at the same time Faraday's law must be obeyed. At higher voltages the film becomes thicker and more current is required to cause this increase in thickness. Table II. and the following table IV. give data upon the current-time curve for different voltages.

TABLE IV.

Formation of the Film.[1]

Time.	5 Volts.		10 Volts.		20 Volts.		50 Volts.		100 Volts.
Sec.	1	2	3	4	5	6	7	8	9
0	.070	.070	.150	.150	.200	.200	200	....	240
10	.010	.010	.020	.020	.055	.040	100	130	...
20	.004	.004	.010	.010	.020	.020	60	...	...
30	.003	.003	.004	.004	.012	.010	38	30	60
40	.002	.002	.003	.003	.007	.007	20	20	...
50	...	...	.002	.002	.004	.003	17	...	...
60	...	...	...	...	.003	.002	12	...	4

[1] Readings were taken with aluminium strips with an area of ten square centimeters. In specimens 7, 8, and 9 the current was adjusted by resistances so as not to exceed the limit of the milliameter. The results are given in amperes. All these strips were formed with direct current.

Integrating the preceding table, IV., for the coulombs, the following results are obtained and tabulated below:

TABLE V.

Number of Specimen.	Formed at: Volts.	Coulombs.
1	5	.8
2	5	.8
3	10	1.9
4	10	1.9
5	20	3.0
6	20	3.8
7	50	2.8
8	50	4.5
9	100	...
11	120	10.0

From these coulombs, we may calculate the thickness of the film if we know its composition. The film is not an oxide, but in the case under consideration the film varies between the limits $Al(OH)_3$ and $AlPO_4$. The chemical composition of the film will be discussed more fully in a future paper.

The thickness of the film that forms on aluminium anodes in phosphate solutions has been calculated from the coulombs. The results are given below:

	Thickness.	
	$Al(OH)_3$	$AlPO_4$
Voltage.	Centimeters.	Centimeters.
10	.000013	.000025
50	.000032	.000063
120	.000064	.000126

Calculated thicknesses are given in the above table for the limits of chemical composition.

The other methods of obtaining the thickness of the film are by mechanical measurements of the film, by optical methods from interference colors and by detaching the film.

The author has tried a variety of methods of measuring the thickness of the plate mechanically by means of a self-setting micrometer-screw caliper. This instrument read to .0001 cm. Several experiments seemed to indicate that the aluminium plate was just a little thicker where the film was formed than where there was no film. These readings are too close to the limits of error to be of any value by themselves. Results obtained with a spherometer were not satisfactory, because of the flexibility of the aluminium plates. By repeating this experiment with firm plates more satisfactory results would probably be obtained.

Colors of Thin Films.

Films formed on aluminium anodes show interference colors which have been used by Mr. C. I. Zimmerman for calculating their thickness. But before taking up the special case of aluminium anodes, it may be well to consider how general is this film formation. In 1826, Nobili observed that lead acetate gave chromatic rings (called Nobili rings) upon anodes, due to the precipitation of thin films of lead peroxide. Others (among whom Becquerel and Gassiot may be mentioned) introduced interesting and valuable variations into Nobili's process. Copper oxide (Buchner, Watt and others) may be precipitated in the same way. Böttger and Ludersdorff have succeeded in producing upon zinc, films that show interference colors. Oxides of manganese, bismuth, cobalt, nickel, etc., have been formed by Watt into thin films that show rich interference colors. A complete list of the workers in this field would be very long[2] indeed. In recent years the French papers have given much attention to this branch of electrochemistry. (See L'Electrochimie and Chronique Industrielle.) These references show that films of metallic oxides formed by electrochemical means are common. The films that form on aluminium anodes have some similarities to this class of films; but they are unique because of their enormous dielectric strength.

These films, formed on aluminium anodes, show interference colors, as has been pointed out by Beetz, Pollak, Norden, Isenberg and others. Mr. C. I. Zimmerman has been the first to apply optical methods to the measuring of the thickness of these films. He says: "By means of these interference color phenomena, the writer has estimated the thickness of the films. They range from less than 0.000005 cm. to, in exceptional cases, more than 0.000050 cm. in thickness."

Mr. Zimmerman has given the color changes for increasing thicknesses of the film, but he has omitted the changes in color obtained on rotating the plate. In the well-known equation[4]

$$nl = 2Ti \cos B$$

there are two variations that may produce the same result. The colors observed for a given thickness, T, on varying the angle B can pass through only a limited number of changes. The one exception to this statement occurs when the index of refraction approaches unity, but this case need not be considered for the most probable value of i appears to be 1.5 for these anode films. The corrections to be made if i is not 1.5 are as follows. If i equals 2.0, add 20 per cent; but if i equals 1.3, subtract 30 per cent. The solution of problems by the above equation is best done by first solving many trial cases. The limiting value of cos B should be calculated. A complete presentation of these optical methods would be long, tedious and out of place, so we will give the experimental data and the conclusions.

[2] See Elsas, Wied. Ann., 29, 331, 1886. A. H. Hiorns, Text-Book on Metal-Coloring and Bronzing, 1892. M. Paul Malherbe. Metal-Coloring and Bronzing, M. Paul Malherbe, Translation from the French, in Scientific American Supplement, No. 1473, March 26, 1904. Rieder, Zeitschrift für Elektrochemie, 9, 911, Nov. 19, 1903.

[4] In this equation, the terms signify quantities as follows:
n = integral number of wave lengths in air.
l = wave length of light in air.
B = angle of incidence on the second surface of the thin plate.
T = thickness of thin plate.
i = index of refraction.

In table VI. the author gives his observations upon films formed in disodium hydrogen phosphate. Column I. contains the colors observed holding the aluminium plate at right angles to the line of sight; and column V. contains the colors

TABLE VI.

COLORS OF ALUMINIUM PLATE FORMED IN SATURATED DISODIUM HYDROGEN PHOSPHATE (Na_2HPO_4).

Volts.	Colors on rotating.				
	I.	II.	III.	IV.	V.
0	white	white	white	white	white
25	blue	blue	blue	blue	red
50	yellow	green	yellow	green	green
75	brown	brown	green	green	red
100	blue	purple	purple	blue	green

observed when the plate had been rotated so as to appear nearly on edge. Columns II., III. and IV. give the colors seen for intermediate degrees of rotation.

The two methods of calculation yield concordant results. At 25 volts, the calculated value of the thickness of the film formed in phosphate solution is .00002 centimeter, and at 100 volts the calculated value is .00008 centimeters.

DETACHED FILMS.

It was necessary to find a way of removing the metallic aluminium and yet of leaving the film intact. For this purpose, aluminium anodes that had been formed at 125 volts in disodium hydrogen phosphate were used as anodes in a copper sulphate solution. Current was passed until holes from 1 to 3 millimeters diameter had been eaten through the aluminium sheet. The smaller holes, on rinsing the sheet in distilled water and drying, had transparent, colorless films still intact. I detached some of these, put them in a test-tube where they floated around like plates of mica and showed irridescence similar to that displayed by the original aluminium surface, when

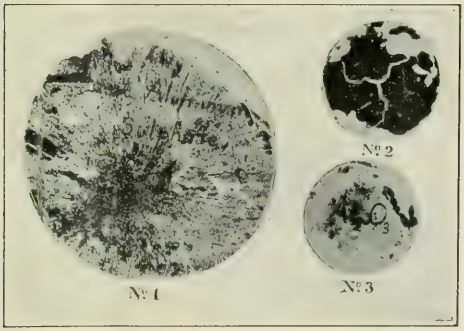


FIG. 2.—PHOTOGRAPHS.

No. 1.—Basic aluminium film formed by using aluminium foil as anode in dilute sulphuric acid. (This photograph was taken by Mr. Bellinger, whom I wish to thank.)——No. 2.—Original aluminium foil.——No. 3.—Aluminium oxide (suboxide) formed by aluminium foil in gas flame. This contains a film of transparent aluminium, since it can be burnt, it conducts electricity, and in reflected light gives the lustre and appearance of metallic aluminium.

viewed from different angles. On the large holes, a rim of film was generally left on each side. Cutting some of these holes through their center and examining under a microscope, the edge of the film was visible. In a film which I could sharply focus, the thickness did not apper much greater than the cross-hairs in the microscope, hence, from this I should judge the thickness to be .0005 cm. or less.

Professor C. E. Mendenhall kindly undertook to measure the thickness of the film. This was done by placing three of the films that bridge the holes in the aluminium plate between two plates of glass. The thickness was found by a direct-vision spectroscope to be 0.0007 centimeter or less. This was for a film formed on an aluminium plate at 125 volts in a saturated solution of disodium hydrogen phosphate, at room temperature.

The thickness obtained by these two methods were much higher than expected. The reasons for this result are, first, the film tends to crumple and fold somewhat, and, second, it is probable that the film became *thicker* in the copper sulphate under the action of the current. Another method of obtaining the film separate from the aluminium is to form the film on a very thin sheet of aluminium.

At the Washington meeting of the American Electrochemical Society, the author showed some transparent films that had been formed out of an anode of aluminium foil. This aluminium foil had a thickness of .00008 centimeter. The author has formed transparent films, both with sulphuric acid and phosphoric acid. This shows that films of the thickness .00016 centimeters may be formed. Further results of value may be expected by a systematic use of this method.

The electrolyte causes large variations in the thickness of the films formed on aluminium anodes. Sulphates give thickest films and citric acid thinnest films. These considerations hold only where comparison is made at the same voltage. From Cook's experiments upon gain in weight of aluminium anodes in sulphuric acid, the author has calculated the thickness of the films and finds them several times thicker than the films formed in phosphate solutions. Again, optical methods show that a film formed at 20 volts in sulphuric acid is *thicker* than a film formed at 100 volts in a phosphate solution.

SUMMARY.

In this investigation it was necessary to use as many methods as possible for measuring the thickness of the film that forms on aluminium anodes. The gain in weight of the aluminium anode gives the minimum limits of the thickness, while the coulombs required for the formation of the film gives the maximum limits. The thickness can also be calculated from the interference colors. This method is the easiest and most accurate means of comparing films formed in different electrolytes, at different temperatures, etc. The most valuable method for obtaining the absolute thickness is the actual separation of the film from the aluminium. A suitable solvent for the aluminium is required. The use of formed aluminium plates in mercury may solve the problem. Aside from chemical means there is the electrical one of using the aluminium as anode and cathode alternately, so that the film is loosened. Another device is the use of aluminium foil as anode.

In conclusion, the film that forms on aluminium anodes may be said to be roughly a linear function of the voltage. On this basis the thickness of the film in phosphate solution is as follows:

Volts.	Thickness. Centimeter.
1	.000001
20	.00002
80	.00008
320	.0003

The usefulness of this work is apparent as regards the aluminium electrolytic condenser; but in other directions it is also important. Many formulas have been deduced by various experimenters to express the polarisation of aluminium anodes, but these are only *empirical*, since they have no foundation in the properties and dimensions of the insulating film. A further study of this film may reveal the real mechanical and electrical forces that act on molecules and ions at the moment of electrolytic separation. Anodes of other metals need study; this is particularly true of chromium, which has been assigned such a unique position by Hittorf and by Morgan and Duff.[1]

[1] Jour. Am. Chem. Soc., 22, 33 (1900).

A CONTRIBUTION TO THE THEORY OF THE JUNGNER-EDISON ACCUMULATOR WITH CONSTANT ELECTROLYTE.

By M. U. Schoop.

I.

In *Electrical World and Engineer* of June 29, 1901, Dr. E. F. Roeber has developed a theory showing that if an alkaline accumulator with constant electrolyte (so-called "oxygen-lift cell") is charged or discharged, considerable concentration changes must occur at the electrodes, due to the different migration velocities of the K and OH ions. However, the total content of KOH in the electrolyte—or in other words, the average concentration of the electrolyte—remains constant during every phase of charge and discharge. Therefore, when the concentration of the solution in the pores of one electrode increases, the concentration in the pores of the other electrode must simultaneously decrease. Of course, as soon as gas is developed at the end of a charge, water is decomposed and the concentration of the electrolyte is thereby changed.

If two molecules KOH are decomposed by the current, the reaction may be represented by the following formulas:

$$KOH = K \left\{ \begin{matrix} OH \\ + \\ OH \end{matrix} \right.$$

$$KOH = K \left\{ \begin{matrix} OH \\ + \\ OH \end{matrix} \right.$$

further,

$$K \left\{ \begin{matrix} HOH \\ + \\ HOH \end{matrix} \right. = 2KOH + H_2$$

and

$$\left\{ \begin{matrix} OH \\ + \\ OH \end{matrix} \right. = H_2O + O$$

H_2 and O reacting with the active materials at the two electrodes.

If, for instance, $2 \times 96{,}540$ coulombs pass through the battery (96,540 coulombs = electric charge of one monovalent gramion), two monovalent gramions OH are involved in the reaction at the negative (iron) electrode, and two monovalent gramions K in the reaction at the positive (nickel) electrode. We may write, according to Roeber's suggestion[1], the reactions at the two electrodes during discharge of the battery

(1) $Fe + 2OH = FeO + H_2O$

and

(2) $NiO_2 + 2K + H_2O = NiO + 2KOH$

These equations, in combination with the above equation of the reaction, show at once that after $2 \times 96{,}540$ coulombs have passed, one molecule of water has been formed at the iron electrode and simultaneously one molecule of water has disappeared at the nickel electrode so that the electrolyte has become more dilute at the iron electrode and more concentrated at the nickel electrode. The result of the electrolytic action would, therefore, be a simple electrolytic transfer of oxygen from the nickel electrode (where the oxygen must be assumed to exist under high pressure) to the iron electrode (where the oxygen must be assumed to exist under low pressure).

On the basis of the value 0.25 for Hittorf's transport number of K in a 30 per cent KOH solution, Roeber arrives at the following final result. When the battery gives out in discharge one coulomb, the changes in the battery due to the migration of the ions and to the electrochemical processes at the electrodes, consist in the transfer of $\frac{1}{2 \times 96{,}540} - 0.0000052$ grammolecule O or 0.000083 gram O from the nickel plate to the iron plate, the transfer of 0.0000026 grammolecule KOH = 0.000146 gram KOH from the solution at the iron terminal to the solution at the nickel terminal, and finally the transfer of 0.0000052 grammolecule H_2O or 0.000094 gram water from the solution at the nickel terminal to the solution at the iron terminal. This result is entirely independent of the chemical nature of the metals used for the electrodes, as long as we have to do with this type of battery, with a constant total concentration of KOH solution.

[1] In reality both active materials at the end of a charge of the battery are surely hydrates; anhydrides are electrolytically inactive. Jungner writes for the charged active iron material $Fe + (HOH)_2$, and for the charged active nickel material $NiO_2 + (HOH)_2$.

II.

The correctness of Roeber's theory can be proven by experiments. It is the purpose of this article to call attention to an experimental method, not yet well known, which was suggested by Dr. E. Sieg and worked out by the author, and to discuss some results of a great many measurements made with this method with nickel, iron and cadmium electrodes.

The method consists essentially in the measurement of the changes of weight, caused by electrolysis in the electrodes (including the electrolyte in their pores). This may be done either by weighing an electrode on a scale before and after the passage of the current, or by suspending the electrode to be tested between two corresponding opposite electrodes from the beam of a suitable balance, as shown in Fig. 1. The latter method was used in these experiments.

Let us designate with H the volume of the pores in the

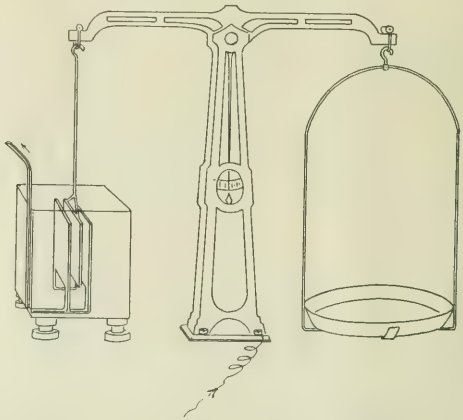


FIG. 1.—BALANCE FOR STUDYING CONCENTRATION CHANGES AND DIFFUSION PHENOMENA IN STORAGE-BATTERY PLATES.

active material of an electrode. These pores are filled with electrolyte. At the moment in which we begin the discharge, the volume H of the pores may be $= H_0$. We then get for any moment

$$H = H_0 - vit$$

where t is the time in hours after the current has begun to pass, i the constant discharge current in amperes, and v the increase of volume of the active mass per ampere-hour. Since the volume of the pores filled with liquid changes, the weight of the liquid in the pores also changes, and the decrease of weight, due to the decrease of volume of electrolyte, is $vits_0$, where s_0 is the specific gravity of the solution at the beginning of discharge.

Another change of the weight of the liquid which fills the pores of the volume H, is due to the fact that the concentration of the liquid is different at the beginning and at the end of the experiment. This increase of weight during the time t is

$$-(s_0 - s)\ (H_0 - vit)$$

where $-(s_0 - s)$ represents the increase of specific gravity of the liquid in the pores during the experiment.

We may assume that the change of absolute weight of the

solid electrode is 0.3 grams per ampere hour (solely due to the lifting of oxygen from one plate to the other); this will probably be very nearly correct.

By the addition of the different items which make up the total change of weight, we now get the total change of the absolute weight p in grams.

$$p - p_0 = \pm (0.3 - vs_0)it + (s_0 - s)(H_0 - vit)$$

where p_0 is the weight of the electrode at the time $t = 0$.

This formula gives the absolute change of weight of the electrode, inclusive the weight of the liquid in the pores. This change of weight of an electrode during discharge might be determined by removing the electrode from the liquid, allowing the liquid to drop off for a certain time and then placing the plate on a scale. But it would be impossible to analyze the different items making up the total change of weight by this method. Moreover, this method is not accurate. Much more accurate results, which agree among themselves much better, are obtained by the other method already noticed, in which the change of weight of the electrode is measured in the electrolyte itself.

With this method it is, of course, in general, necessary to take into account the loss of weight of the electrode equal to the weight of the displaced electrolyte. For our present case, however, in which the electrolyte between the two plates (outside of the pores) has a constant concentration for the whole time of a discharge or charge, the above formula is exact without further terms of correction. On the other hand, in experiments with lead electrodes in H_2SO_4, this point must be duly taken into consideration, since the loss of weight of the electrode in the acid solution equal to that of the displaced acid, will be quite different at the beginning and at the end of the discharge on account of the fact that the concentration of the external acid solution has changed.

The question as to the formulas which we have to give to the active materials during the reaction of the alkaline accumulator has not yet been definitely settled, nor do we know exactly the specific weights of the nickel and iron hydrates. It is therefore not yet possible to give exact numerical data for the various items in the above equations. The value of the following experiments is to be found mainly in the experimental proof of the concentration changes of the solution in the pores of the electrodes, taking place during and after the passage of a current.

The method using a susended electrode[2] offers the advantage that it is not necessary to take the electrode out of the electrolyte in order to determine the variations of its weight, nor is it necessary to open the circuit. The balance used in this method should be rather compact, but should, nevertheless, have sufficient sensibility. The bearings are preferably made of hardened steel and it is then possible to introduce the current to the suspended electrode from the external circuit, through the stationary frame of the balance; this is a requirement of great importance for the successful application of the method. A large e. m. f., in form of a storage battery of about 300 ampere-hours capacity was connected in series with the cell, so that it was easy to modify the requirements of the experiment at will; this is not possible, if, as usual, the cell is discharged through a wire resistance; moreover, there is not the inconvenience of being obliged to regulate the resistance continually in order to keep the current constant.

The following quantities were measured:

(*a*) The voltage at the terminals of the whole accumulator.

(*b*) The voltage of the suspended electrode against a small auxiliary nickel or iron plate.

(*c*) The change of weight of the suspended electrode during the passage of the current and after interruption of the current.

(*d*) The temperature of the electrolyte.

(*e*) The current.

In order to avoid any variations of temperature during the passage of the current, a large glass vessel was used as container. This also offered the advantage that it was possible to see any gas bubbles on the plates, any changes in color of the electrodes or the electrolyte, and to observe any particles of active mass dropping off or carried out of the pockets.

Moreover, it is not only possible to measure the changes of weight and volume of each electrode, but also to study conveniently the phenomena of diffusion—which are so important for many electrochemical purposes—during and after electrolysis. Attention may here be called to the comparative experiments[3] made by the author with a positive Plante plate and a positive pasted plate, both plates having exactly the same capacity for a one-hour discharge; these experiments prove the great difference in the speed of diffusion between the acid in the pores of the plates and the outside solution.

It is true that in the alkaline accumulator the diffusion of the electrolyte is probably not of such fundamental importance as is the case with the lead accumulator, since in the latter case the chemical reaction which furnishes the electrical energy is the change of the active masses into lead sulphate. Nevertheless, such tests of nickel or iron electrodes are very valuable, since it thus becomes possible to directly observe in a most simple manner not only the concentration changes of the liquid in the pores, but also the volume changes of the active masses, as is evident from the above formulas.

While the good diffusion of the acid in the lead accumulator has been stated to be the vital condition for the perfect operation of the lead cell, we may say correspondingly that the maintenance of good contact between the active mass and the support plates through which the current passes to the active mass from the external circuit, is the vital requirement for the good behavior of the alkaline accumulator. This will be evident, if we take into consideration the well-known very low conductivity of the active materials which, to get a better conductivity, must be mixed with graphite and subjected to strong pressure. It is thus clear why it must be of the greatest importance to ascertain the variation of the volume of the active materials, since the phenomenon of the expansion and contraction of the active materials must be intimately connected with the change of the total conductivity of the active materials.

There is no doubt that the exact knowledge of the variations of the volume of the active masses is also of importance for the lead accumulator, although disregard of this point leads to other consequences, since it will result in a dropping off of active material and in a distortion of the plates. It is peculiar that in the literature on the lead accumulator the variations of the volume of the active materials has nearly always been neglected; as an exception I mention the well-known book of Dolezalek on the theory of the lead accumulator.

The final result of the electrolytic action of the lead accumulator during discharge consists in the formation of lead sulphate on both electrodes and simultaneously there is rather a considerable increase of volume on both plates. We will find that the opposite is the case with the electrodes of the alkaline accumulator; in this case there is a diminution of the volume of both electrodes during discharge and an increase of volume during charge; this change of volume is small with the iron and cadmium electrode, but considerable with the nickel electrode, and in this case it is the greater, the more the plate has been discharged.

III.

The electrodes used in the experiments were taken from an old Jungner accumulator. All had the same dimensions, namely, 75 x 200 x 5 mm. The electrodes consisted each of

[2] See also Ein Beitrag zur Kenntnis der Diffusionsvorgange an Akkumulatorelektroden. By M. U. Schoop. Stuttgart; F. Enke, 1903.

[3] Elek. Zeit., Heft 12, 1903.

three pocket units, made of perforated nickel-steel and containing in their interior the active materials. The three pockets were placed side by side and clipped at the top and bottom by means of folded strips of the same material. (The electrodes now made by the Jungner-Akkumulator Aktiebolaget in Sweden are somewhat different, and have proven better, especially concerning the voltage drop).

The first experiments were made with a cell which consisted of two nickel electrodes and an iron electrode, the latter being suspended on the scale. As auxiliary measuring electrode a fully charged small plate of nickel was used which after completion of the charge, showed an e. m. f. of 1.5 volts against the iron electrode, after four days, however, only 1.35 volts; after this time this value remained constant and the auxiliary small plate remained continually in the cell.

The color of a charged iron electrode is distinctly dark brown. During discharge the color changes to a dark olive green. The charged nickel electrode shows generally a light brown shade, which, however, does not interfere with the bright lustre of the outer surface and which soon disappears, after the discharge has begun. The brown oxide film of the auxiliary nickel electrode did not disappear even after it had been used for several months.

Discharge of the Iron Electrode with 0.5 Ampere

Of many measurements made with iron electrodes, I will first give the following results, represented by the curves in

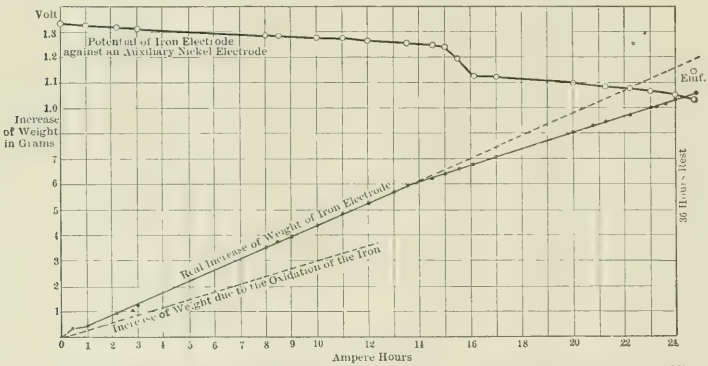


FIG. 2. BEHAVIOR OF IRON ELECTRODE WITH LOW DISCHARGE RATE (0.5 AMP.)

Fig. 2. This was an extraordinarily slow discharge of about fifty hours (i = 0.5 ampere) and care had to be taken to keep the temperature of the room constant; regulation of the current did not become necessary as a result of the arrangement of the experiment with the battery mentioned above.

The discharge voltage of the iron electrode started with 1.34 volt; within thirty hours (corresponding to 15 ampere-hours) the voltage decreased gradually and slowly to 1.2 volts; it then dropped rapidly and assumed a value of about 1 volt, which it maintained for a long time. After 24.7 ampere hours were given out by the cell the value 1.03 volt was reached. Since the main purpose of the experiment was to determine the changes of weight of an iron electrode if discharged with a very small current, the experiment was now discontinued.

The phenomenon of a "double voltage" (indicated by the sudden bend near the center of the discharge curve) is observed not only with the iron electrode, but also with nickel electrodes. With the latter, however, I have observed the sudden bend in the voltage curve only at the end of the discharge, while the moment at which the voltage suddenly drops with the iron electrode, can be changed within certain limits by the method of preparing the active iron material; in general this point occurs in the discharge curve of the iron electrode at an earlier and therefore more unfavorable phase of the discharge.

The curve showing the change of weight is nearly a straight line, if we neglect the small variations from the straight line at the beginning of the discharge. After thirteen ampere-hours have been given out by the cell, the direction of the straight line is changed somewhat. This moment corresponds to the new reaction which has now started in the active iron material. The increase of weight per ampere-hour is 0.44 gram for the first portion of the discharge curve and somewhat smaller for the second portion.

This simple experiment shows that the process at the iron electrode during discharge cannot be simply a combination of the active material with oxygen since it would then evidently be difficult to understand why the active material should undergo a contraction due to the addition of oxygen. An easier explanation of the contraction of the active iron material would be found in the assumption that the active material at the beginning of the charge is a hydrate, say of the formula,

If the process at the iron electrode during discharge would be simply oxidation, the increase of the absolute weight of the iron electrode per ampere-hour would be 0.3 gram (oxygen) and exactly this increase should have been found in our weighing experiments, if the supposition was fulfilled that the concentration of the liquid in the pores is equal to that of the free external solution, and that the volume of the active iron material has not changed during the passage of the current. With the very small discharge current of 0.5 amperes we may be justified in assuming that the concentration of the liquid in the pores differs very little from that of the free solution ouside of the pores between the two plates during the whole time of discharge; for this reason the excess of the increase of weight over that due to oxidation, as shown in Fig. 2, must be assumed to be due to a contraction of the active mass. If the absolute weight of the active mass filled into the pockets, as well as its specific weight are known at the beginning and at the end of an experiment, and if the volume of plate as well as the concentration of the free electrolyte are given, it would be easy to calculate the change of volume numerically. For the electrodes of the lead accumulator I have made such calculations in my pamphlet on "diffusion phenomena on lead electrodes, mentioned above.

The increase of weight which an electrode would undergo if no concentration changes are allowed to develop in the electrolyte in the pores during the passage of the current, may be determined in two ways. The first way is the method used in the above experiment, by discharging the cell with an exceedingly small current. The second method is to discharge the cell more quickly with a larger current and to observe the changes of weight during the passage of the current as well as after the discharge has been stopped. The diagrams thus obtained are of special interest and are suitable for an investigation of the diffusion phenomena in the interior of the plates.

With the first method, one measures the absolute change of weight of the solid electrode, plus the change of the loss of weight equal to the weight of displaced electrolyte, on account

of the changed volume of the active mass; on the other hand, the influence of concentration changes in the liquid in the pores (that is, the factor $— (s_0 — s)$, due to the different migration velocities of the K and OH ions) may be considered as so small that it can be neglected, since diffusion and convection have time to destroy all concentration changes which tend to develop.

With the second method, after completion of the discharge, the cell is left at rest in order to accomplish that all concentration differences, existing between the liquid in the pores and the external free liquid, are gradually destroyed by diffusion and convection. After this has taken place, the change of weight measured (compared with the weight at the beginning of the discharge) equals again the absolute change of weight of solid electrode, plus the change of the loss of weight, equal to the weight of the displaced liquid, caused by the changed volume of the active material.

It is thus possible to control the accuracy of one of the above two methods by means of the other, under the supposition that during one experiment no self-discharge nor any development of gas occurs at the electrode.

Discharge of the Iron Electrode with 15 Amperes.

It is, indeed, possible to get a fairly good agreement between the results of both methods. The same electrode which was used in the experiment of Fig. 2, was then discharged with

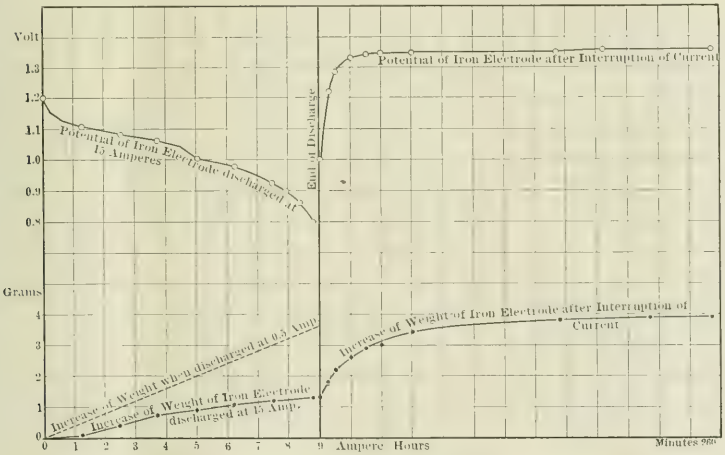


FIG. 3. BEHAVIOR OF IRON ELECTRODE WITH HIGH DISCHARGE RATE (15 AMP.)

15 amperes, the results being given in Fig. 3. The average voltage at the terminals, which is of no special interest for our purpose, is, of course, much more unfavorable with this very high discharge rate than in the discharge with the thirty times smaller current (0.5 amperes of Fig. 2). The sudden voltage drop in the middle part of the discharge curve can still be seen, although it is less evident.

The curve of the change of weight has a shape which differs quantitatively from that in Fig. 2. It will be seen especially that the increase of weight is more than one-half smaller than in the former experiment.

It is improbable that the reactions taking place at the active materials of the plate are different from those in a slow discharge. The reason of the difference in the weight curves is, therefore, to be found in the different diffusion of the electrolyte under the different conditions of the two experiments. In other words, such diagrams show us the phenomena of diffusion at the electrodes at different discharge rates.

As will be seen from the above equations, the electrolyte in the pores of the iron electrode becomes more dilute on account of the formation of water during discharge, while the electrolyte in the pores of the nickel electrode becomes more concentrated since water here disappears. Other things being equal, the concentration change will be the greater the higher the rate of discharge or charge, *i. e.*, the shorter the time in which diffusion and convection are able to counteract the concentration differences developing on account of the electrochemical action. It is thus evident that the higher the discharge rate, the better should be the agreement between the observed concentration changes in the liquid in the pores, and those calculated by Roeber's method.

If, at the end of discharge, the circuit is broken, diffusion and convection will begin to annihilate the concentration differences between the dilute solution in the pores of the iron electrode and the external, more concentrated solution. The iron electrode must therefore increase in weight until there are no longer any concentration differences.

A small increase of weight of the suspended iron electrode after the interruption of the current is observed even after the discharge with the low rate of 0.5 amperes (Fig. 2). The increase in weight was 0.95 gram after the cell had been left at rest for thirty-six hours, and simultaneously the e. m. f. increased to 1.145 volts.

Much more significant are the results obtained in the experiment with the high discharge rate of 15 amperes. After the current has been interrupted, the external electrolyte which had a specific gravity of about 1.25 in all experiments, diffuses vehemently into the pores of the plate and raises the concentration of the greatly diluted solution in the pores. The result is that the weight of the electrode, while left at rest, first increases rapidly and afterwards more slowly; after four hours the increase of weight is 2.6 grams, so that the total increase of weight for the 8.7 ampere hours taken out of the plate, is $1.3 + 2.6 = 3.9$ grams. With a discharge rate of 0.5 amperes the corresponding value for the same number of ampere hours was 3.8 grams.

The well-known phenomenon of the e. m. f. of a lead accumulator rising again, when left at rest after a discharge at a high rate, has been shown by Dolezelak to be simply due to diffusion of the acid; the e. m. f. increases until there is no longer any diffusion of acid between the electrolyte in the pores and the outside electrolyte. With a lead peroxide plate (where the e. m. f. is in linear relation to the acid concentration) it is thus possible to use the curve showing the diffusion while the cell is at rest, in order to conclude from it correctly what the simultaneous changes of the e. m. f. are.

In Fig. 3 the change of the e. m. f. in the time, after the circuit has been opened, after completion of the discharge with 15 amperes, is shown in the upper right hand part of the diagram. The curve first rises rapidly and assumes after one hour the value of 1.35 volts and changes in the next three hours only very slightly, namely, by 0.01 volt only.

No exact measurements have yet been made on the relation between the concentration of the electrolyte and the e. m. f. But from those observations which I have made I would conclude that for equal porosity of the active materials, the iron

electrode is somewhat more capable of regaining its potential, when left at rest, than the nickel electrode. It is very probable that in the nickel electrode the temperature changes of the electrolyte are of much greater importance than concentration changes, and therefore the nickel-iron accumulator will probably have a higher temperature coefficient than its old rival.

The results of weighings of a cadmium electrode of the same size as the iron electrode discussed before, are given in Fig. 4. The voltage and weight curves are not essentially

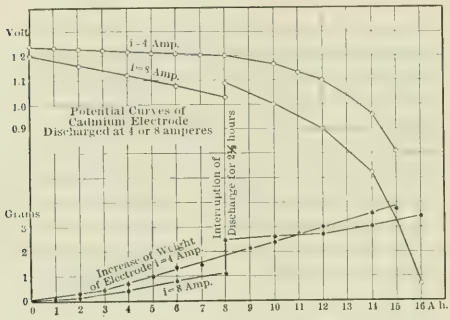


FIG. 4.—BEHAVIOR OF CADMIUM ELECTRODE

different from those of the iron electrode, but the relation between discharge rate and change of weight is more evident than with the iron electrode. A so-called "double voltage" is not observed with the cadmium electrode.

(To be concluded in our next issue.)

GERMAN BUNSEN SOCIETY.

Report of the Ninth General Meeting in Bonn.

By H. Danneel, Ph. D.

The ninth general meeting of the German Bunsen Society for Applied Physical Chemistry (formerly the German Electrochemical Society) was held in Bonn on May 13th and 14th. There were, in the whole, 150 members and guests present, among them numerous official delegates of institutions and of German and foreign societies. Prof. Roscoe, Prof. Landolt and Prof. Ramsay were elected honorary members. The next general meeting will be held in Karlsruhe in the week following Whitsunday, 1905.

Meeting of May 13.

The papers presented at the first session dealt mainly with various scientific questions involved in iron metallurgy.

The Application of the Phase Rule to Alloys of Iron and Carbon.

A paper on this subject was presented by Prof. Bakhius Roozeboom, of Amsterdam. The solidification of iron, containing carbon, and the simultaneous formation of iron-carbon compounds are of special importance for the metallurgy of steel. Attempts to explain these phenomena on the basis of the phase rule were first made in 1896. Since that time the researches of various investigators have led to the development of very concise ideas concerning these phenomena. The author gave a diagram showing the changes with temperature of alloys of iron and carbon, with temperatures varying between 1500° and 500° C., and for alloys containing various proportions of carbon, between 0 and 8 per cent.[1] The author also exhibited a number of other diagrams concerning which, however, our knowledge is not yet complete in all details. A question not yet decided, is whether cementite (Fe_3C) is stable at higher temperatures; according to the author, it seems that cementite is unstable at all temperatures.

Hardening Steel by Sudden Cooling.

Prof. Heyn presented a paper on the compounds of Fe and C, which are formed when steel is hardened by sudden cooling. An eutectic mixture remains unchanged; otherwise non-homogeneous mixtures of ferrite, cementite, pearlite, troostite, etc., are formed. Troostite is formed especially if the velocity of cooling is small. If manganese is present, the formation of troostite is greatly counteracted. The author exhibited a great many lantern slides showing clearly the structure containing the various Fe—C compounds.

Manufacture of Calcium.

In a paper on this subject, Dr. Rathenau first gave an historical review of the methods devised for winning calcium. It was first made as amalgam. Bunsen precipitated it from a saturated $CaCl_2$ solution, Mathiessen from salt mixtures and Borchers[2] produced it in spongy form by electrolysis of fused $CaCl_2$. The author stated that the efficiency of the Borchers process is not high and his calcium has a purity of 90 per cent only.

Suther and Redlich have worked out a new electrolytic method in the laboratory of the Allgemeine Elektricitäts Gesellschaft. The feature of their method is that the cathode is made to just touch the surface of the fused calcium chloride; it is gradually raised during operation in such a way that the calcium deposited at the end of the cathode remains just in contact with the fused bath. Calcium rods are thus obtained of 3 to 4 cm. diameter and 20 to 30 cm. length.

Replying to a question of Prof. Van't Hoff, whether it would pay to make Al-Ca alloys, Dr. Rathenau replied that these can be obtained only in small quantities. Muthmann stated that it is quite easy to produce calcium from a mixture of two thirds of $CaCl_2$ and one-third CaF_2.

Dissociation Phenomena at High Temperatures.

In a paper on this subject Dr. Loeb remarked that the condition which must be fulfilled to start a chemical reaction, is the presence of free valencies. Dissociation may be considered as a process by which substances in which many of the valencies are saturated, are changed into constituents in which only a small portion of the valencies is saturated. From this point of view, dissociation must exist, to enable any chemical reaction to start. Electrolytic dissociation is only a special case, the peculiar feature of which is that the concentration of the products of dissociation, *i. e.*, the ions, is very great. This is the reason why ions react with a much greater velocity than the parts which are formed by dissociation of organic substances. The supposition that all substances are always dissociated (although only a small part of the same may be dissociated) is a good means for explaining reactions of organic chemistry.

To study the phenomena of dissociation the author heats the substances in a glass vessel which is provided with a refrigerator, and in which a platinum wire is heated electrically. In general it is not possible to detect the real products of dissociation, since they are stable for a short time only. But it is often possible to conclude what they are, from the final products. For instance, benzene changes at high temperatures diphenyl and H_2, and the process must be assumed to be $C_6H_6 = C_6H_5 + H$. Afterwards C_6H_5 and H form diphenyl and hydrogen molecules. In this way the author gave the theory of the decomposition of chloroform, chloral, benzyl chloride, benzal chloride, and benzotrichloride. As an ex-

[1] In all essential points this diagram is the same as that given in Dr. W. Campbell's article, on page 49 of our February issue, 1904. It is, therefore, not reproduced here. Ed.

[2] Electrochemical Industry, Vol. I. (1902-1903), page 104; see also page 143 and 122.

ample, may be given his scheme of the decomposition of benzyl chloride:

$$2C_6H_5CH_2Cl \quad 2C_6H_5CH \uparrow 2HCl$$
$$\|$$
$$C_6H_5CHCHC_6H_5$$

In all these reactions, the starting materials which contain four-valent carbon change into substances with carbon of a lower valency, but these are unstable and, therefore, form new and more saturated complex compounds. One must assume that the intermediary products can exist for a short time; under certain conditions it is possible to obtain them, for instance, CO, methyl, triphenyl, etc.

The author believes that valency is a function of the conditions of the experiment, for instance, a function of pressure, temperature and the medium in which the reaction takes place. High temperatures decrease the number of valencies, for instance, at high temperatures a mixture of HCl and NH_3 is not capable of reaction, since the free valencies required for the reaction are missing. If the temperature is increased, or if the substances are brought into a suitable medium, or if the pressure is increased, new valencies are formed and NH_4Cl is formed. The substances assume the maximum number of valencies at an absolute temperature zero.

COLLOIDS.

In a paper on this subject, Dr. E. JORDIS expressed the opinion that the theories that have so far been offered on colloids are wrong. He has fitted up for himself the following scheme. Electrolytes, which, with proper additions, are capable of forming colloids, are in a special state, in a certain intermediary state which is specially suitable for the change into a colloid. The formation of colloids is only possible, if at the same time impurities are present. This is true also for the colloidal metal solutions of Bredig because the distilled water always contains dust, gases and impurities. All colloids are amphoteric, so as to react as well with acids as with alkalis. If the affinity with acid is greater, the liquid becomes alkaline. Colloids are not essentially, but only gradually different from crystalloids. According to the conditions of the experiment, the colloids may travel either towards the anode or the cathode under the influence of the electric current.

PASSIVITY OF METALS.

Dr. WOLF JOHANNES MUELLER stated that there are two theories for the explanation of the passive state of metals. One theory assumes that an oxide film is formed on the metal, the other that the metal itself assumes a new condition. There are certain points which speak against the first theory. For instance, iron reflects in air 60 per cent of the light; this reflection is not changed when the iron assumes the passive state, so that no optically active oxide layer can be present. The author tries to explain the passive state by the electronic theory. According to Riecke and Drude, there exists in a metal always a dissociation into positively charged metal atoms and into negative electrons. An equilibrium exists between both. On account of the great affinity of the metal to the positive electrons, only the negative electrons are capable of free movement, and for this reason the transport of electricity through a metal is accomplished by the negative electrons only.

If a metal is used as anode, positive electrons pass into the solution, either in form of ions or in form of positive electrons; in the latter case the electrolyte is oxidized. Whether the one or the other phenomenon takes place, is determind by the force with which the positive electrons are held by the metallic atoms. This force is measured by the potential of the electrode, and, according to Hittorf, it is the smaller, the greater the valency with which the metal passes into solution. If this force is very small, the metal does no longer pass into solution at all; in other words, it is in the passive state. If a metal assumes the passive state as anode it is because it assumes a higher valency; for this reason only such metals can assume the passive state which can assume different valencies.

At the anode there is a large potential drop because the metal with its high conductivity is in contact with the electrolyte with its smaller conductivity. Negative electrons are there sucked out, and the condition of electric neutrality is maintained by positive electrons passing into the solution. This is the easier the higher the valency with which the metal passes into solution. We may say that by the negative electrons passing away, the dissociation in the metal is increased so that the metallic atoms assume more positive charges. The reverse phenomenon is found at the cathode. There the negative electrons arrive and decrease the dissociation: metal = positive metallic atoms + negative electrons, and the metal assumes its lowest valency. If a cathodically polarized metal is then again made anode it passes into solution with a lower valency, *i. e.*, it has become active.

Metals also become passive by immersion in certain solutions, for instance, in HNO_3. The author explains this by local currents, which pass between the metal and the impurities present in every metal. The depolarizing property of the electrolyte decides whether the cathodic effect, producing activity, or the anodic effect, producing passivity, is greater. The phenomena of the passive state are very clearly exhibited by manganese. At a sufficiently high current density, 0.07 to 0.15 ampere per square centimeter, manganese in a slightly acidulated sodium phosphate solution passes into solution, with simultaneous development of oxygen. This produces considerable variations of the potential of the electrode.

There was considerable discussion of this paper. Bredig remarked that the argument brought forward by the author against the oxide film theory might not be decisive, since it is a question how thick a film must be to be optically active. To produce a chemical action the film can be very thin. A film of 10^{-8} cm. is sufficient to completely change the chemical properties of the metal.

Owing to limitations of space the report of the other papers presented at the meeting is reserved for our next issue.

ADAPTABILITY OF ARTIFICIAL GRAPHITE ARTICLES.

BY C. L. COLLINS, JR. E. E.

Graphite articles manufactured by the Acheson process need no introduction. The principal characteristics are great purity, high electrical conductivity, lubricating properties, and resistance to oxidizing and disintegrating action. They are manufactured in a manner which avoids the use of the hard vitrified clay bonds usually associated with graphite articles. Being pure graphite with all the characteristics of this form of carbon, they can be cut or machined with the greatest ease and at slight expense. Some of the possibilities of this feature were pointed out in a paper on "Graphite Electrodes in Electrometallurgical Processes," read before the American Electrochemical Society at their inaugural meeting in Philadelphia, April 4, 1902, and again briefly in an article on "Graphite Electrodes in Electrolytic Work," which appeared in ELECTROCHEMICAL INDUSTRY, September, 1902. It will doubtless interest electrochemists to know what has actually been accomplished in this connection in regular commercial work, and with this end in view the following data, including some figures covering exact costs, have been collected.

FIG. 1.—JOINING FURNACE ELECTRODES.

A method of using electrodes for electric furnace work, so that no waste occurs, is shown in Fig. 1. This represents an old elec-

trode, or stub *c*, which, while in use was consumed as close to the metal holder *a* as permissible. A new electrode *b* is then joined to *a*, and *c* in turn connected to *b*. Heretofore the part *c* has been wasted.

The form of threaded joint used is given a slight taper, which, with the graphite electrodes, gives the maximum strength. The two adjoining shoulders should be faced so as to make a tight fit. The metal holder *a* is also given a slight taper at the outer surface, and by a form of clamp the whole is supported over the surface from above. This ring *a*,

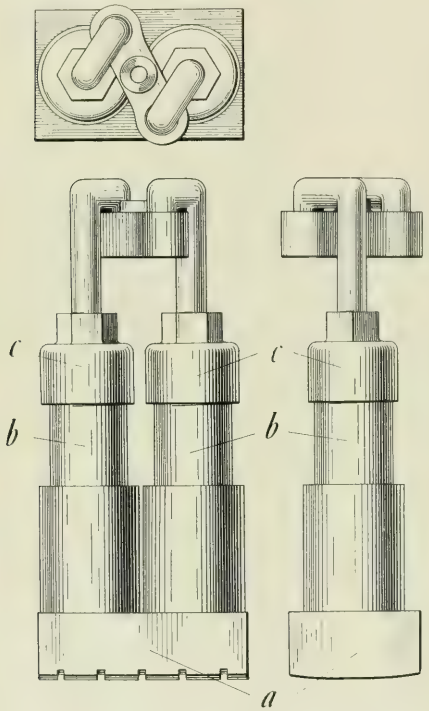


FIG. 2.—ELECTRODES USED IN ACKER PROCESS FOR ELECTROLYZING FUSED SODIUM CHLORIDE.

which is of brass, and the supports from above also act as the conductors to the graphite electrodes. By this method the furnace must be shut down for electrode renewals, but in the process in question this is not objectionable as the furnace is shut down in any case at certain definite intervals to remove the charge. It is evident, however, that by a slight modification a new electrode could be joined to the end of one in use, and these fed into the furnace continuously as consumed.

In order that some idea may be gained of the practicability of this method, it may be mentioned that in one process over a carload of graphite electrodes per month is being machined and joined in this manner without waste. The cost of machining both ends of an electrode 6 inches in diameter, is about fifty cents per electrode, and for an 8-inch electrode, about sixty cents, which includes actual labor, cost of tool steel and repairs. In either case about 3 inches of the electrode length is sacrificed costing fifty-nine cents for the 6-inch and ninety-seven cents for the 8-inch. Thus the total cost of a male and female joint is $1.09 for the 6-inch and $1.57 for the 8-inch, or about 11½ and 10 per cent, respectively, of the cost of the electrodes themselves in lengths of 48 inches.

The method is especially applicable for electric furnace processes in the manufacture of ferro-alloys or where very heavy current and the concentration of the energy in a small space are desired. With electrodes 8 inches in diameter over 5,000 amperes may be used without apparent resistance or heating at the joints and with 6 inches from 3,000 to 4,500 amperes. One electrochemist has even used 7,500 amperes in a jointed 6-inch graphite electrode for certain work without difficulty. With a 6-inch amorphous carbon electrode not more than 1,500 amperes could be carried efficiently.

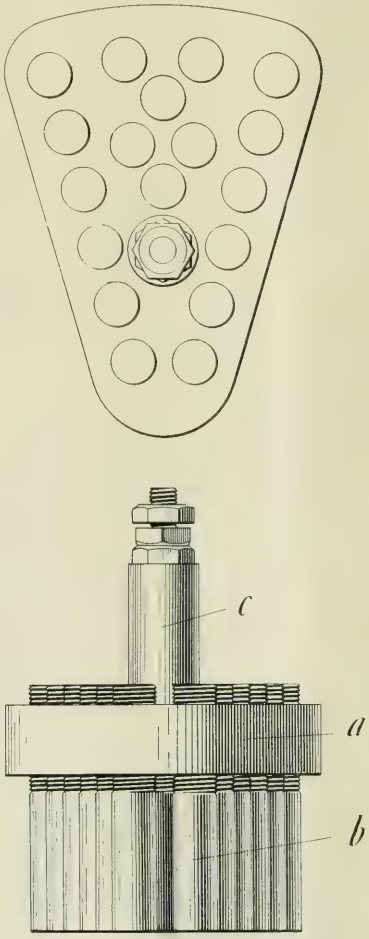


FIG. 3.—ELECTRODE USED IN RHODIN PROCESS FOR ELECTROLYSIS OF SODIUM CHLORIDE SOLUTION.

Another manufacturer in electrometallurgical work, by using large assembled terminals consisting of a specific form of electrode holder and a peculiar arrangement of several graphite electrodes, has effected a saving in the electrode cost per ton of output in his furnace of approximately 20 per cent. This is in comparison with former methods when amorphous carbons were employed and takes into account not only the cost of the electrodes, but also that of the repair fittings, labor of assembling, placing in the furnace, etc. The comparative tests were very thorough, extending over several years, and

represent a consumption of several hundred thousand pounds of electrodes per annum.

The cost of threading the graphite electrodes in this case amounts to only fifteen-hundredths of a cent per pound of electrodes. In using graphite only 132 pounds per terminal is necessary, on account of its high electrical conductivity, as against 352 pounds for the amorphous carbon. There is little difference in the cost of fitting and assembling, and, as the graphite costs more per pound, the total investment per terminal is practically the same in either case. The saving is, therefore, due to a longer life and consequently fewer numbers of electrodes to be handled, but is also due to the ease of handling and consequent saving in labor. A further and very important factor is the *greater uniformity of the graphite article*. Special stress is laid on this latter point, for the former high cost of the amorphous carbons was principally due to the fact that the average life of these articles was considerably below the maximum, whereas with the graphite electrode there is practically no variation and definite results can be expected. It is of the utmost importance that a furnace run does not have to be interrupted to renew electrodes before the operation is complete. A further factor in the saving is the fact that the stubs of the graphite electrodes are not wasted, but can be joined and used as new electrodes by a simple form of threaded joint.

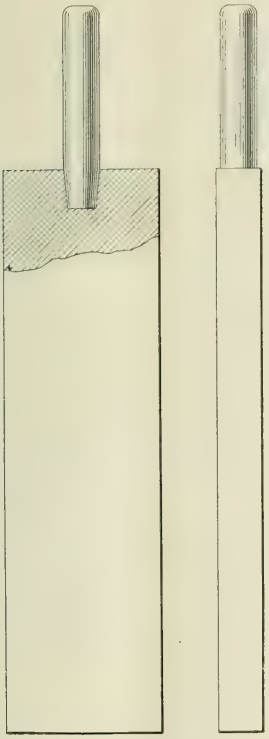


FIG. 4.—SIMPLE ANODE FOR ELECTROLYTIC WORK.

The style of anode used in the Acker process for the manufacture of chlorine and caustic soda with a fused electrolyte and a fused lead cathode is well known, and is shown in Fig. 2. The working anode proper is the lower face of the block *a*, which is grooved and rounded to allow of the ready escape of the anode gases. A number of these blocks are arranged side by side in each cell. Two graphite rods *b*, each 5 inches in diameter, are threaded into the upper face of *a* and act as the leading-in conductors from the metal terminal *c*. These terminals are cast-iron caps screwed over the tops of the rods *b* and cross-connected by heavy brass bars, to which the circuit is finally connected. The graphite rods *b* are encased in tile pipes to protect them from oxidation, which would otherwise take place slowly at the working temperature of the cell. The spaces between the metal caps and the upper edges of the tile pipes are made air-tight by thoroughly cementing with a suitable fire-clay mixture, which is afterwards baked. Each anode block carries a working current of 2250 amperes. The cost of threading both ends of each round electrode is only three cents, and the cost of drilling, tapping and corrugating the block, eleven cents, or a total cost for the machine work upon the graphite of only seventeen cents per anode. The advantage of this form lies principally in the saving resulting from the high electrical conductivity of the graphite electrodes and the use of the minimum possible electrode material for conducting the current from the metal caps to the anode block *a*.

FIG. 5.—ANODE USED IN McDONALD DIAPHRAGM CELL.

In Rhodin's process the cell is circular in form, and is divided into a number of segmental compartments, in each of which is a graphite anode of special design. One of these anodes, of which there are six per cell, is shown in Fig. 3. It consists of a triangular graphite block *a*, which also acts as the cover and fits tightly in its anode compartment. Through the block *a* a number of 1¼-inch graphite rods *c* are threaded. The threading allows these to be lowered as they disintegrate at the ends. The total current used per anode is about 150 amperes, and is conducted to the block by a 2-inch graphite leading-in rod *c*. The cost of drilling and tapping the block and threading the rods is about $2.25 per anode.

A simpler form of anode for electrolytic work is shown in Fig. 4. This illustrates one of the fundamental principles in graphite electrode work, viz., the use of a leading-in rod designed to utilize the high electrical conductivity of graphite and a working slab designed to give the maximum surface for its weight and still be of sufficient thickness to allow for disintegration. In this case a rod 1⅝ inches in diameter x 9 inches in length, carrying a current of 46 amperes, is used in connection with a 2 x 7 x 25 inch slab. Only one side of the slab is used as working face, the anode being turned, exposing a fresh face, when seriously corroded. A rod 1⅝ inches in diameter has also been used to carry 58 amperes without appreciable drop. A very simple taper joint is used and gives no trouble. With proper tools a very few minutes suffices to ream the hole and taper the rod, and as it is done by the man tending the cells, it practically adds nothing to the cost. In any case it is more than offset by the saving in electrode weight.

The saving in graphite, however, is not the only advantage which is realized from this form of anode, inasmuch as the holes through the covers of the cell are much smaller and easier then to pack, if the entire cross-section of the anode slab were brought through the cover. As these anodes are near together the construction of the cover itself is simplified by the avoidance of narrow sections. Five inches would have to be added to the length of the anode slab if the rod connection could not be used.

FIG. 6.—GRAPHITE BUSHING.

In Fig. 5 a similar form is shown, a ¾-inch lead rod being used in place of graphite. The lead rod is screwed into a 4 x 4 x 14 inch graphite block, the total current carried being 60 amperes. All four sides act as working faces. The end of the graphite block, into which the lead rod is inserted, is boiled in paraffine and gives no trouble due to corrosion at the contact. In all future work, however, a graphite rod 1½ inches in diameter is to replace the lead conductor. This form is used in the McDonald diaphragm process, both in the manufacture of bleaching powder and caustic soda, and in the chlorination of gold ores.

The illustrations given above all relate to the use of graphite articles in electrochemical processes. In such work graphite

is used not solely on account of its adaptability, but because of other valuable properties, such as purity, high electrical conductivity and resistance to oxidizing and disintegrating action. A more striking illustration, however, of the use of graphite on account of its adaptability, or the ease of machining, is shown by the bushings in Fig. 6. These bushings are about one-half inch in diameter and are used in connection with rheostat work. Five thousand of these bushings were made up from solid graphite rods on a screw machine by a boy in twenty-seven hours without a single defective piece. The cost was one-tenth cent for the machining, and one-tenth cent for the graphite, or a total cost of two-tenths cent per bushing. As far as the requirements of the work are concerned, amorphous carbon bushings would be equally satisfactory, but amorphous carbon bushings of the size and shape shown which must necessarily be molded articles, cost from two and one-half to three cents per piece.

A similar saving can be effected in the case of the small plungers used in dash pots in connection with arc lamps and circuit breaker time relays. We know of one case where small molded graphite plungers were being supplied at $6.00 per dozen corresponding to about $15.00 per pound. Graphite plungers machined to the same size from solid rods cost about fifty cents per pound.

The contacts used in circuit breakers are usually of some irregular shape and are clamped tightly in holders of similar section. For this purpose either molded carbon or machined graphite is satisfactory, the latter having the higher conductivity. The graphite contacts, however, possess other decided advantages, such as non-arcing properties, which characteristic is of considerable value where a circuit is interrupted constantly, and where the current has some magnitude.

In conclusion it may simply be said that the use of graphite articles is not limited to the electrochemical field nor to work requiring articles of high electrical conductivity, purity, resistance to oxidizing and disintegrating action, and lubricating properties. Its sphere of usefulness embraces all the lines of work in which the ordinary forms of carbon have heretofore been used. It is generally more satisfactory than carbon, and in some cases very much less expensive. Users of any form of molded carbon articles can profitably investigate the cost of similar graphite articles.

ELECTROMETALLURGY OF IRON AND STEEL

In the metallurgy of iron and steel the use of the electric furnace has so far been mainly successful on a commercial scale for the solution of two special problems. The one is the manufacture of ferro-alloys, the other the production of special steels. For the production of ferro-alloys it is the ease of producing very high temperatures by means of the electric furnace which has made its application preferable and in some cases necessary, on account of the high temperature of reduction of the oxides (of titanium, etc.) to be reduced. On the other hand, the features which render the electric furnace very suitable for the manufacture of special steels, are the ease of control, the cleanliness of operation, and the absolute prevention of impurities being introduced into the charge from furnace gases. However, these are not the only problems in which electrochemists have tried to introduce the electric furnace in the iron and steel industry. The big problem—that of the reduction of iron ores and the manufacture of iron and steel from the ores—has repeatedly been attacked, although no process of this kind has so far been able to prove its practicability on a large commercial scale.

A great amount of such pioneer work has been done in Europe. The reason is a peculiar one which has really nothing to do with iron and steel. When some years ago it was found that calcium carbide could be easily made in the electric furnace and that by means of the simple reaction of calcium carbide with water, it was possible to get acetylene, promising to be of great importance for the lighting industry, there was started a great boom, and wherever there was a water-power a calcium carbide plant was erected in Europe. It must be understood that the calcium carbide industry in Europe is not in the hands of a single company, as it is in this country. The result was over-production, a collapse of prices and a serious crisis in the calcium carbide industry of Europe. The question was now what to do with electric furnace plants which had been erected and in this crisis nothing seems to have attracted the attention of the European electrometallurgical engineers to a greater degree than the possibilities of electric furnace processes in the iron and steel industries. In former issues we have described in detail nearly all the more important attempts which have been made in this direction.

The matter has become of great actual importance in this country on account of the interest which the Canadian Government has taken in this matter, with a view of introducing an electric iron and steel process on a large scale in Canada where large water-powers and cheap iron ores are available. We have already noticed (page 48 and 198 of this volume) that a commission, appointed by the Canadian Government, and headed by Dr. Eugene Haanel, was sent to Europe to investigate the different electric furnace processes in question, and that the committee has recently returned, convinced that its trip had been entirely successful.

A summary of the main facts ascertained by the committee and embodied in its report to the Canadian Government has recently been given in the "Canadian Manufacturer" from which we take the following passages. For a description of the Keller furnace which takes such a prominent place in the report of the commission, we may refer our readers to an article by Mr. Bennie in our January issue, 1903, page 162.

Keller Furnace.

By far the most important experiments witnessed by the commission were those made by Mr. Keller, of Keller, Leleux & Co. in Livet, France. Some 90 tons of iron ore were used to show the economic production of pig iron by the electric process. The furnaces employed for these experiments were the furnaces used in the regular work of the company for making the various ferro-alloys, such as ferro-silicon, ferro-chrome, etc. The company at the time of the visit of the commission were under contract to furnish ferro-silicon to the Russian Government, but generously interrupted their pressing regular work to undertake the making of experiments for the commission. The furnace employed is of the resistance type, and consists of two iron castings of square cross-section, forming two shafts communicating with each other at their lower end by means of a lateral canal. The cases are lined with refractory material. The base of each shaft is formed by a carbon block. These blocks are in electric communication on the exterior of the furnace by means of copper bars. The carbon electrodes to which electric current is distributed pass two-thirds of their length into the shaft. The electrodes are prisms 72 cm. (28 inches) in diameter and 135 cm. (53 inches) long. Three sets of experiments were made, as follows: 1. Electric reduction of iron ore and obtaining different classes of pig, gray, white and mottled. 2. Electric reduction of iron ore containing a definite amount of carbon in the charge, with a view of ascertaining the amount of electric energy absorbed in the production of 1 ton of pig iron. 3. The manufacture of ordinary steel of good quality from the pig manufactured in the preceding experiments.

The different classes of pig iron were obtained without difficulty, and the furnaces throughout the experiments worked quietly and without the slightest accident, the gas discharging on top in flickering flames, showing that the gas resulting from the reduction of the ore escaped at low pressure. The workmen employed were ordinary Italian laborers without any special training. A number of castings, such as columns,

pulleys, gear wheels, plates, &c., were made, the metal drawn directly from the furnace. The castings showed sharp edges, a comparatively smooth surface, and were sound throughout.

For the determination of the electric energy absorbed, the voltmeter and ammeter employed to measure the volts and amperes were calibrated in the laboratory of the director of the electrical department of the University of Grenoble, who also ascertained the power factor of the alternator furnishing the electric energy. The electric energy absorbed per ton of pig was found to be 0.226 horse-power year.

COST OF PROCESS.

1.	Ore (hematite metallic iron 55 per cent. 1,842 tons at $1.50 per ton	$2.76
2.	Coke for reduction, 0.33 tons at $7 per ton	2.31
3.	Consumption of electrodes at $5 per 220 pounds	0.77
4.	Lime	0.30
5.	Electric energy, 0.226 horse-power year at $10 per each horse-power year	2.26
6.	Labor at $1.50 per day	0.90
7.	Different materials	0.20
8.	General expenses	0.40
9.	Repairs maintenance, etc.	0.20
10.	Amortization (machinery and buildings)	0.50
	Total, exclusive of royalty	$10.60

To satisfy the commission, Mr. Keller made experiments to illustrate his process of making steel. The details of the operation and the figures relating to his experiments are in the hands of Prof. Harbord, the English metallurgist, who accompanied the commission.

In regard to other processes it was found that Mr. Harmet of St. Etienne, who published papers and obtained patents on the electric process for smelting iron and making steel and Mr. Gin of Paris, who has obtained a patent for the production of steel from scrap, have as yet no plant in operation by which their methods might be tested.

PROSPECTS OF THE ELECTRIC FURNACE.

In his general conclusion, Dr. Haanel says: "It must be pointed out that the results obtained at Livet were the results of experiments in furnaces not specially adapted to the work required to be done. With the improved furnaces of which the commission has secured detailed drawings, permitting on account of higher column of charge a more effective use of the reducing power of the carbon monoxide evoloved, and the employment of machinery for charging the furnace to reduce the cost of labor, a much better figure than the one given will result."

The processes of electric smelting must yet be regarded as in the experimental stage, no plant existing at present where iron ore is commercially reduced to pig by the electric process. The more remarkable therefore it appears that experiments made off hand, so to say, in furnaces not at all designed to be used for the production of pig, should give a figure of cost which would enable an electric plant properly designed and managed to compete with the blast furnace. It is, moreover, reasonable to expect that, as experience in electric smelting accumulates, the design of the electric furnace best suited to the conditions of the high temperatures with which the metallurgist has to deal will undergo changes which will reduce the absorption of electric energy to a minimum. The electric engineer will also be called upon by the new industry to design electric plants specially suited to the conditions of electric smelting.

When it is considered that the electric process is applicable to the smelting of all other ores, such as copper, nickel, silver, etc., that the furnaces are of simple construction and the regulation of the heat supply is under perfect control, we may expect that the application of electric energy to the extraction of metals from their ores will not be long delayed, and that familiarity with handling large currents, and experience gained in electric smelting will result in displacing some of the costly and complicated methods by comparatively simple and economic processes. The immediate effect of a plant erected for the smelting of iron ores which will demonstrate the economic production of pig and the making of steel will arouse the faith of the industrial world in the new metallurgy, and other industries dependent upon electricity as the agent or to which electricity can be applied will follow as a consequence in the wake of this power plant.

MANUFACTURE OF SPECIAL STEELS.

At Gysinge, Sweden, steel of superior quality is made by the smelting together of charcoal, pig and scrap in an electric furnace of the induction type—that is to say, a furnace without electrodes. This process corresponds to the crucible steel process, but it has certain advantages over the latter in that the melted materials at no time during the operation are exposed to gases, some of which when absorbed deleteriously affect the quality of the product. The furnace worked quietly and regularly, producing on the average 4 tons of steel in twenty-four hours. Tapping occurring every six hours, 0.116 electric horse-power years were required per ton of product. The cost at the rate of $10 per electric horse-power a year would be $1.16 per ton of product. At Kortfors, Sweden, the Heroult process of making steel is in operation, but the furnace is at present employed in the making of ferro-silicon.

At Lapras, France, steel is also made from melted scrap. The process differs from that at Gysinge, in that it permits of the purification of the materials employed, two slags being made for that purpose, and carburization is effected in the furnace by carbon briquettes. The furnace is of the tilting pattern, consisting of an iron casing lined with dolomite brick. The bottom of the furnace is filled on top of the lining with crushed dolomite, upon which the charge reposes. Two electrodes pass through water-cooled joints in the roof of the furnace. The electrodes are vertical and parallel, and are adjusted vertically either by hand or a specially constructed regulator. An alternating current of 4000 amperes of 110 volts is distributed to the electrodes. Different classes of steel are made by the company at a cost per electric energy absorbed of $1.54 per ton of ingot. The selling price of the steel varies from 363 francs 60 centimes to 123 francs 60 centimes per ton, depending upon quality.

Interesting experiments were made for the commission at this plant in the production of pig from the ore in a very simple furnace consisting of an iron box of rectangular cross sections, open on top and lined with refractory material. The bottom of the furnace in communication with the iron casing constituted one terminal of the electric circuit. A carbon electrode of square cross-section and about 3 feet in length, placed vertically in the open top of the furnace, constituted the other terminal. By hand regulation this electrode could be lowered or raised within the furnace. Thirty charges of ore were made during the working, and thirteen taps of metal and slag were taken.

MEETING OF THE FARADAY SOCIETY.

An ordinary meeting of the Faraday Society was held on June 9, the president, Dr. J. W. Swan, being in the chair.

M. Adolphe Minet presented the first part of a paper on the electric furnace; its origin, transformations and applications. The paper discusses the growth of the furnace from the historical point of view, and then proposes a new classification which is worked out in minute detail in the form of a table. A full bibliography of the electric furnace completes this section of the paper. The discussion was postponed until the autumn, when the author will complete his study and fully illustrate his subject.

Dr. F. M. Perkin described a form of porous diaphragm which he has found convenient for laboratory use. It consists of two perforated concentric porcelain cylinders packed

in between with brown paper, asbestos, or other material, depending on the use to which the diaphragm is to be put.

Mr. G. T. Beilby read a paper on the hard and soft states in metals. The wide range of the phenomena which are directly or indirectly associated with the hard and soft states in metals indicates that a knowledge of these states is of fundamental importance. An exclusively crystalline theory of metal structure, even when stretched to its widest limits, is insufficient to fully explain these phenomena. But the crystalline is not the only form of solid aggregate; the movement of the molecules in the liquid state may be so suddenly arrested that they have no time to fall into the regular formation of the crystalline state, so that the solid which results is amorphous, not crystalline. A suddenly congealed liquid may be likened to an instaneous photograph of the rapidly moving molecules of the liquid state.

The views advanced were based on the author's earlier observations on surface flow in crystalline solids. The evidence afforded by the micro-structure has been supplemented by observations on the other properties of metals in the hard and soft states, and the view was now advanced that these states are perfectly distinct phases. This is shown by the mechanical, electrical, optical, and thermo-chemical properties, as well as by the micro-structure. The soft phase is crystalline and the hard phase is amorphous.

The transformation of hard into soft is effected by heat and takes place at a definite transition temperature. On either side of the transition point the various properties are characteristic and distinct; for instance, an e. m. f. of 120 microvolts may be developed in a thermo-junction of silver in the two phases. The e. m. f. falls to zero after the junction has been heated to 260° for a few seconds. Silver leaf, which is opaque and highly reflecting below the transition temperature, becomes transparent and very much less reflecting if kept for a time at a temperature a little above the point.

The transformation from hard to soft is thermally irreversible, but is readily effected mechanically. The reverse transformation—soft to hard—takes place when the metal is deformed by overstrain, however slight. It takes place through an intermediate mobile phase in which the molecules have a freedom analogous to that in the liquid phase. This freedom is produced by motion directly imparted to the molecules during the slipping of one portion of the material over another. The state of the mobile phase is somewhat analogous to that of an undercooled liquid. This transformation, soft-intermediate-hard, while it occurs at every moving surface, does so as a rule in extremely thin layers. The layers of the hard phase, which result supply a rigid casing for the unaltered crystalline elements, and thereby give a granular and cellular structure to metal which has been overstrained by having any kind of work done on it. The co-existence of the two phases in this way accounts for the variety of structure which may be developed in malleable and ductile metals.

In the discussion of the paper, Dr. T. M. Lowry said that the temperature which Mr. Beilby called the transition point, was not a true transition point, such as exists, for example, in sulphur at 96° C., at which the rhombic passes into the monoclinic phase, but really the stability-limit; that is, the temperature at which the mobility of the molecules enables a change which has been trying to take place all along to do so at a visible velocity.

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By George P. Scholl, Ph. D.

Electric Furnaces and Furnace Products.

Manufacture of Sulphide of Aluminium and Alloys of Aluminium.—Miyagoro Onda, Nagoya, Japan. Patent 760, 554, May 24, 1904. Application filed October 14, 1903.

The first step of the process consists in comminuting the raw materials into a powder and mixing them intimately. These materials are: Oxide of aluminium, or ores containing it, charcoal, coke or other carbonaceous matter, and a metallic sulphide or sulphate, the heat of formation of which is lower than that of the corresponding aluminium salts. This mixture is formed into balls of pressure, after about five parts of its weight of coal tar have been added to increase its compactness. The balls are then baked in a retort and broken up again into pieces of the size of a bean. They are charged into an electric furnace, the walls of which are made of firebrick, while the bottom and the lining are formed of carbon. The latter constitutes one electrode, the other being formed by a hollow carbon rod, which passes centrally through the furnace cover. On both sides of the furnace there are receptacles, which communicate through a canal with the melting chamber of the furnace, one of them being intended for the reception of the melted aluminium alloy, and the other for the aluminium sulphide. An opening is provided for the escape of the gases, and the silicon sulphide formed in the reaction. The charge in the furnace is subjected to a temperature of about 2000° C., by producing an electric arc between the electrodes. The current density is 20 to 40 amperes per square inch of carbon rod, at 50 to 100 volts. When it is intended to produce an aluminium iron alloy containing, say, 10 per cent of aluminium, simultaneously with aluminium sulphide, the charge consists of bauxite, 100 parts; charcoal, 40 parts, and sulphide of iron, 127.5 parts. The reactions are stated to take place as follows: The iron oxide is first reduced to metal by the carbon, while at the proper temperature the sulphide of iron interacts with

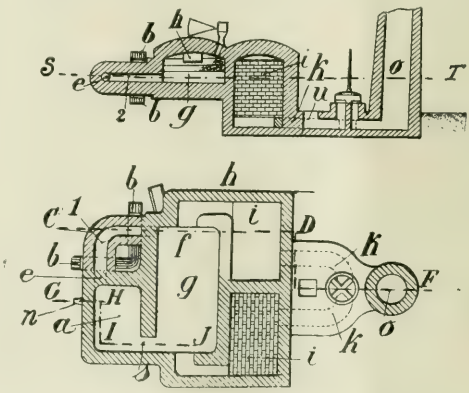


FIG. 1.—STEEL FURNACE

the other ingredients after equation $3FeS + Al_2O_3 + 3C = 3Fe + Al_2S_3 + 3CO$ and $2FeS + SiO_2 + 2C = 2Fe + SiS_2 + 2CO$. The silicon sulphide volatilizes, the iron greatly aids in the reduction of the alumina by the carbon, and an iron alu-

minium alloy is formed. The reason for using a hollow upper electrode is not disclosed by the inventor.

Electric Furnace.—C. P. E. Schneider, Le Creusot, France. Patent 761,920, June 7, 1904. Application filed October 12, 1903.

The furnace described in this specification belongs to the type of induction furnaces in which the electric current is produced by an alternating magnetic field. In the existing furnaces, which have annular crucibles of approximately uniform section, the great conductivity of the ring of molten metal is said to have resulted in the production of an extremely intense induced current, the reaction of which upon the primary coil produced an unfavorable phase displacement of the primary current. In the present invention the idea therefore has been to impart greater resistance to the molten metallic circuit by constructing it in the form of a tube of small cross-section which communicates at both ends with a chamber of large dimensions containing the greater part of the molten metal. This tube has sufficient inclination so as to insure an active circulation of the metal between the tube and the melting chamber, on account of the difference of density between the hotter and colder parts of the molten mass. The idea is shown embodied in various constructions. Its application to a multiple-chamber Siemens regenerative furnace for the production of steel is shown in Fig. 1 in plan and cross-section. Here *a* and *g* are the two furnace chambers filled with a bath of pig iron, into which the branches 1 and 2 of the V-shaped heating tube open at *c* and *f*. The orifice *e* is preferably slightly above the orifice *f*, so as to cause the metal to circulate from *a* towards *g* through passage *s*. The heating tube is provided with the magnetic heating cores *bb*. Coke or coal of any suitable kind is placed upon the bath of pig metal in the chamber *a*. Owing to the active circulation of the metal due to the heating of the tube 1, 2, the carbon, which dissolves in the molten bath, spreads to the chamber *g*. Ore and the necessary fluxes are introduced into chamber *g* in a uniform manner, which ore fuses in contact with the bath and is reduced by the carbon of the bath. The iron thus produced dissolves in the bath, while the carbonic oxide gas is liberated. The slag which results from the fusion of the gangue and still contains ore, is conducted into chamber *a* through passage *s*. The slag remains in contact with the coke in chamber *a* until its last traces of iron are removed and it has taken up the ash of the coke, when it is run off through a tapping hole *n*. The carbonic oxide may be utilized for heating the chamber *g*. It is burned at its formation above the bath by highly heated air in regeneration chambers *i*, set out with checkerwork of bricks, and communicating with chamber *g* by passages *f*. Each chamber communicates with chimney *o* by a passage *k*, the two conduits *k*, *k*, terminating at a door which conducts the waste gases of one regenerator to the chimney, while it allows the entrance of cold air to the other by orifice *a*. In this manner a high temperature is produced in chamber *g*, which facilitates the fusion of the ore and aids in its partial attack by the carbonic oxide gas, which traverses it in rising from the bath through the mass. This method of attacking the ore by the carbon dissolved in the bath, without mixing the solid carbon with the ore, in combination with the electric furnace comprising tubes and several chambers, and the process of heating a single chamber by the combustion of the carbonic oxide by means of air heated in Siemens regenerators is quite novel. It is stated that the electrical energy employed is utilized principally in order to compensate the losses of heat, and that it may be greatly reduced by careful construction of the envelopes of the furnaces in such a manner as to retain the heat as much as possible. The process is very interesting as showing the continuous development of the electrometallurgy of iron and steel, which is bound to show its possibilities when fostered by the progressive management of such large and well-known works as the Creusot.

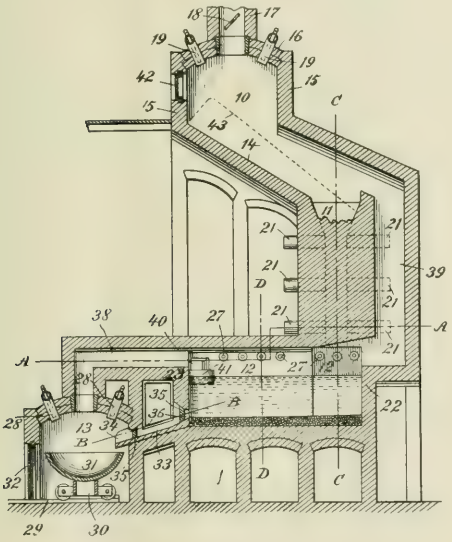


FIG. 2.—GLASS FURNACE.

Glass-Melting Furnace.—G. H. Benjamin, New York. Patent 762,270, June 14, 1904. Application filed January 3, 1903.

The furnace is illustrated in Fig. 2 in vertical section. It consists essentially of three chambers, 10, 11 and 12, of which the first one serves as preliminary heating chamber, the second comprises the electric furnace part proper, and the third constitutes the refining chamber. The charge is introduced through door 42, and slides down on the inclined hearth 14 of the heating chamber. The crown 16 of the latter is located at such a distance above the hearth as to permit a free radiation of flame within the fusion chamber, without touching the material upon the hearth 14. The heating of the chamber is accomplished by means of the hydrocarbon burners 19. The electric chamber 11 connects with the bottom of the heating chamber, and is wider at its bottom than at its top. It is divided into four inclined passages, which are not visible in the figure. Three sets of electrodes 21, 21, of carbon or other suitable material are provided in each passage, which melt the preheated material. After passing the arcs, the molten glass passes into the refining chamber 12, the rear portion 22 of which is wider than the front portion 23. The chamber 12 is between 32 and 48 inches deep, depending upon the character of the glass it is desired to make. On the bottom 25 of the chamber, a layer of chilled glass 24 is allowed to accumulate in order to prevent injury to the bottom blocks and their working up into the melted glass. The refining chamber is heated by hydrocarbon burners 27. The material is here subjected to a lower temperature, so that, when it reaches the front end of the chamber, it is in a condition to be gathered by hand through the gathering doors 40 or drawn into the receptacle 31, through passage 33. The material in receptacle 31 may be maintained at the required temperature in the chamber 13 by means of the hydrocarbon burners 28 until it is required for use. A plug 35 closes the opening 36, to prevent the flow of glass along the passage 33. A flue for carrying off the waste gases leads from the top of chamber 13 into the refining chamber 11 and a flue 39 leads from the latter around the electric chamber 11 into chamber 10. This construction, it is claimed, prevents the free carbon, which is stated to be contained occasionally in the products of combustion from the heating and refining chamber, from coming into contact with

and coloring the glass materials, while they are in the zone of the highest temperature.

Electrolytic Production of Metals and Compounds.

Process of Recovering Metals from Ores or Sands.—W. J. Jory and J. H. Jory, San Francisco, Cal. Patent 760,539, May 24, 1904. Application filed April 7, 1903.

The electrolytic part of the proposed process is carried out in the apparatus patented by the same inventors and described in Electrochemical Industry, Vol. II., p. 238. Among the various processes outlined are the following. Gold ores containing copper and iron sulphides are treated by introducing a solution of sulphuric acid or other single acid in the pulverizing apparatus, the acid acting upon ferric sulphide to produce a solution of ferric sulphate, to act as solvent for both the copper and the gold contents of the ore. When the latter contains gold, arsenic and antimony in connection with sulphur combined with this or other metals, the procedure consists in adding ammonium sulphide to the ore in the pulverizing apparatus, it being stated that the reaction which takes place between the arsenic or antimony and the reagent forms a solution which dissolves the gold and keeps it in solution. In treating a silver ore containing copper and silver sulphide, in some cases a sulphite of some alkaline earth or alkali metal is used, "preferably sodium hyposulphite," to which, during the process of pulverization, a solution of ammonia in such quantity as will produce a decided alkaline reaction, is added. Precise information as to the various processes is lacking. It is also proposed to recover mercury from ores by electrolysis instead of distillation, by pulverizing the ore in contact with preferably an alkaline sulphide with an addition of an alkali hydrate to obtain an alkaline reaction of the solution. The ore pulp, together with the solvent, is then run into tanks provided with filtering beds and remains until the mercury goes in solution. The solution is then filtered off and the mercury deposited in the apparatus described on page 238, as mentioned above. Data as to voltage, current density, strength of solutions, etc., are not given.

Reduction of Nitro Compounds.—Max Buchner, Mannheim, Germany, assignor to C. F. Boehringer & Soehne. Patent 761,284, May 31, 1904. Original application filed September 24, 1900. Divided and refiled December 13, 1902.

The invention consists in the reduction of nitro compounds to amines by passing the electric current through such compounds in acid solution in the presence of lead or a lead salt. The electrolysis is carried out in a vessel divided into two compartments by a porous diaphragm. It is unimportant what material is used for the cathode, as the latter merely serves to convey the current, the process of reduction being solely dependent upon the presence of the above metal in the cathode chamber. It is also immaterial whether the finely divided metal or metallic salt is added to the electrolyte in the cathode chamber. In both cases the reaction proceeds over or by way of the regenerated or recovered metal. The process of the reduction of nitrodenzene to aniline, by the addition of lead chloride to the cathode electrolyte, is carried out as follows. The electrolyte of the anode chamber consists of a 10 per cent solution of sulphuric acid; the anode is any suitable indifferent conductor. The cathode contains a mixture of five hundred parts, by weight, of fuming hydrochloric acid, five hundred parts, by weight, of water, 123 parts, by weight, of nitrobenzene, and fifty parts, by weight, of lead chloride. The cathode is a cylinder of platinum. The nitrobenzene is constantly stirred by a rapidly revolving stirrer, and is constantly replenished when consumed. A cooling device, such as a cooling coil, is preferably used in the cathode compartment. The current density is about 1900 amperes per square millimeter (evidently a misprint). The current is maintained until regular liberation of hydrogen takes place and becomes visible. After the process of electrolysis is completed, the lead of the lead chloride is found to have separated in the form of fine metallic sponge, and no lead is found in the cathode electrolyte. The reduction of nitrobenzene to aniline by the addition of metallic lead to the cathode electrolyte is carried out in substantially the same manner, except that instead of the lead chloride forty parts of finely divided metallic lead are added to the cathode electrolyte.

Preparation of Azo Dyes.—Walter Loeb, Bonn, Germany, Assignor to C. F. Boehringer & Soehne. Patent 761,310, May 31, 1904. Application filed March 16, 1903.

Azo bodies have hitherto been prepared by dissolving or suspending an Amine in acid solution, diazotizing it at a low temperature by means of a nitrite and mixing it with the solution of a coupling compound. Coupling is the property which certain bodies (among them the amines and phenols) possess of combining with diazo compounds to form azo compounds. Coupling compounds are the compounds which take part in such combination, *e. g.*, amines or phenols on the one hand and diazo bodies on the other. Dr. Loeb has succeeded in preparing azo dyes electrochemically in one process by combining diazotation and coupling of the amine with a compound of acid character in the same solution under the influence of the electric current. The principle of the operation is stated to depend on the discharge of NO_2 anions in a nitrite bath at the anode. When an amine is present, its diazotation takes place. Such diazo compounds are, however, very unstable, but by employing coupling compounds in connection with the diazoting reaction, a stable azo dye can be obtained. If a coupling compound of an acid character is present during diazotation, it will at once combine with the diazo compound, which is formed and produce the corresponding azo compound or dye. The amines cannot be used for the process of coupling, on account of their being subject to diazotation by the NO_2 ions. The process is explained by assuming that the reaction of coupling takes place at a much greater rate than the decomposition of the diazo bodies. The process is preferably carried out in a vessel separated into two compartments by a porous diaphragm. A platinum anode is preferable; the cathode may be of any metal. An amine, the coupling compound, preferably in the form of a soluble salt, and nitrite, preferably in the required molecular proprtions, are introduced into the anode compartment, all in aqueous solution or suspension. The reaction is expressed by the following general equation: $RNH_2 + H.R'.OH + HNO_2 = R.N:N.R'.OH + 2H_2O$. The preparation of the sodium salt of aniline-azo-2-naphthol-3.6-disulphonic acid (Ponceau 2 G.) is carried out by preparing an anode bath of 10 parts, by weight, of aniline, 32.7 parts, by weight, of "R acid" (B naphthol disulphonic acid) and 9.1 parts, by weight, of potassium nitrite, stirred with 100 parts of water, and a cathode bath of a dilute potassium hydrate solution. The anode is platinum and the cathode nickel. The current density may be varied from 0.5 to 7.5 amperes per square decimeter, the temperature from 40° to 90° C. After rather more current than is necessary to decompose the nitrite has passed, electrolysis is stopped and the dye isolated from the deep red anode solution as usual. From an anode solution of 10 parts benzidin, 33 parts naphthionic acid, 9.3 parts potassium nitrite and 100 parts water at 60° to 90° C. there results the dyestuff Congo. From 10 parts diamisidine, 13.6 parts sodium salt of B naphthol, 7 parts potassium nitrite and 100 parts water at 60° to 96° C. results a deep violet dye. From 8 parts naphthylamine sulph. acid (1.4), 10.7 parts R acid, 3 parts KNO_2 and 100 parts water, a deep red solution results, from which the dye may be separated by direct evaporation or the addition of salt. From 11 parts sodium salt of toluylene diamine sulph. acid, 11 parts R acid, 6.2 parts KNO_2 and 100 parts water at 15° to 30° C. the dye may be obtained as in the preceding case. The dye tropaeolin 000 No. 1 is obtained from 11 parts sodium salt of sulphanilic acid, 8.5 parts of a naphthol sodium salt, 4.4 parts of KNO_2 and 100 parts water at 15° to 30° C. The dye Rocelline is gotten by using 10 parts sodium salt of 1.4

naphthylamine sulphonic acid, 6.8 parts sodium salt of B naphthol, 3.6 parts KNO_2 and 100 parts water at 15° to 30° C. The dye Hessian brown is obtained from 9.2 parts benzidine, 31.6 parts azo compound prepared from sulphanilic acid and resorcine, 6.9 parts sodium nitrite and 100 parts of water at 20° to 90° C.

Anode and Process of Making Same.—Henry Blackman, New York. Patent 762,227, June 7, 1904. Original application filed December 8, 1896. Divided and refiled April 24, 1903.

The invention relates to the preparation of anodes for electrolytic purposes, especially the electrolysis of sodium chloride. A plate of cast iron, preferably, is oxidized on its surface, so as to convert it into magnetic or electroconductive oxide, until the coating is of sufficient thickness. That part of the plate where it comes into contact with the surface of the electrolyte, is protected by a band of insulating and impervious material, such as glass or a vitreous glaze. The oxidation of the plates is suitably effected by heating them in a retort to form 1000° to 1200° F., and then passing superheated steam over them for eight or ten hours, or until the coating attains a thickness of from one to three milimeters.

A small quantity of naphtha or other light hydrocarbon is advantageously injected into the retort during this process. The oxidation may also be effected by first coating the iron plate with a thin film of some other metal, as tin or bronze, and then exposing it to a current of oxidizing gas, while heated to about 1000° F. or upwards, whereby the film of coating material is stated to disappear. The oxidation may also be brought about by dipping the plates into a bath of fused niter containing a small percentage of peroxide of manganese, which is kept at about 650° F. in an ordinary melting pot, and leaving them until the surfaces are oxidized to the required depth.

STORAGE BATTERIES.

Storage Battery Plate.—E. W. Smith, Philadelphia, Assignor to Electric Storage Battery Co. Patent 760,712, May 24, 1904. Application filed September 10, 1903.

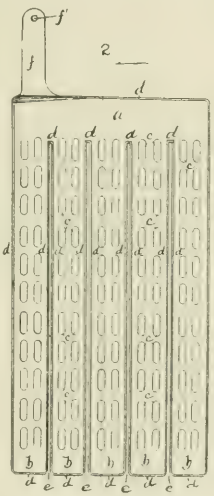


FIG. 3.—STORAGE BATTERY PLATE.

The invention relates to that type of storage battery plate, which comprises a grid, the faces of the respective openings of which are covered by a perforated shield and means are disclosed for securing the perforated cover plate to the grid. Claim No. 1 reads: Means for connecting the grid and perforated cover plate, which comprise grooves in the cover plate, and projections cast from the grid and engaging perforations of the plate and occupying the grooves thereof.

Storage Battery Plate.—Achille Meygret, Paris, France. Patent 760,897, May 24, 1904. Application filed June 29, 1903.

The plate is shown in side elevation in Fig. 3, without the active material. It is preferably made of sheet metal cast, stamped, or otherwise shaped into form. It has an end piece *a* to furnish supports for the strips *b*. Each strip has a series of perforations *c* for holding the active material, which is spread on both sides of the plate. A rib *b* extends around the border of the plate and of each strip *b* for the purpose of stiffening. In order to prevent the loosening of the active material, an elastic sheath, unattackable by the electrolyte, is formed over the surface of the plate by dipping the latter into a bath consisting of castor oil, essence of turpentine, octonitric cellulose and ordinary nitrate of cellulose of commerce, the tetranitrate of cellulose being preferred. In order to allow the electrolyte to reach the active material, this sheath should be rendered porous by chemical or mechanical means.

Storage Battery.—Th. A. Willard, Cleveland. Patent 761,345, May 31, 1904. Application filed September 11, 1903.

The invention concerns a sheath or envelop for separating and containing the storage battery plates. It consists of an envelop of hard rubber, made in two parts, perforated and ribbed, which are joined together with a strip of soft rubber, extending all around the meeting edges of the two parts. After being applied, the strip is vulcanized.

Storage Battery Electrode.—J. von der Poppenburg, Charlottenburg, Germany. Reissue 12,228, June 7, 1904. Original 701,389, June 3, 1902. Application for reissue filed November 12, 1903.

The plate is so constructed that the cross-pieces adapted for dividing or separating the active material protrude from the frame on both sides. They are provided with holes through which pass elastic bars which press against protecting strips which prevent the active material from dropping off. Frames, cross-pieces and bars are made of ebonite.

Electrical Accumulator.—Q. J. B. M. Colletas, Paris, France. Patent 762,803, June 14, 1904. Application filed September 12, 1901. Renewed April 22, 1904.

The battery is composed of a cell made of insulating material, which contains an aqueous solution of sulphate of copper at its highest degree of conductivity, (17 per cent), strongly acidulated with sulphuric acid. The cathode is made of agglomerated retort carbon, preferably associated with metallic arsenic. The body of the anode is also of agglomerated carbon, preferably of double T-shape. A layer of plumbiferous paste is introduced into the space formed by the web and the sides of the double T. The plumbiferous paste is obtained by mixing either red lead or protoxide of lead or chloride of lead with water containing one-twentieth of liquid gelatine, white of eggs, dextrine, liquid starch or vegetable gums, to a firm and plastic consistence. These materials being converted into soluble products upon electrolysis and leaving the remaining active mass in a porous condition. A wire of lead is wound around the paste to keep it in place. The reactions during charge and discharge are claimed to be as follows. A current is passed of at least 2.5 volts, and exceeding one ampere per square decimeter of cathode surface. Under the action of this current the hydrogen is carried to the cathode and takes with it the copper, which is deposited on the cathode in the form of copper hydride (Cu_2H_2), whereas the oxygen at the anode converts the lead into peroxide. Upon discharge the sulphuric acid attacks the copper hydride, forming sulphate of copper and liberating the hydrogen, while at the anode the peroxide of lead is reduced to the oxide. Further data are wanting.

Storage Battery.—Max Schneider, Dresden-Plauen, Germany. Patent 762,847, June 14, 1904. Application filed September 4, 1903.

The battery as illustrated in the specification, shows an outside containing vessel and cover of insulating material, between which vessel and the negative pole electrode is introduced a fibrous cellulose sheet chemically treated with a neutral salt, for insulating purposes. The cylindrical cathode is made of metal or active material as usual, and slit vertically, and a central vertical partition wall extends into the slit. Another insulating sheet as above separates this cathode from the anode, which is built up of a number of downwardly converging lead cones, provided with radial and cross-ribs for retaining active material. These cones are put one above the other and fastened to a tubular core by melting. The whole is then cut in halves, the two parts melted to a fork, and the structure so introduced into the vessel that the fork rests on the above-mentioned partition wall.

Galvanic Elements.

Process of Manufacturing Hard Porous Electrodes for Batteries. H .P .Poerske and G. A. Wedekind, Hamburg, Germany. Patent 760,561, May 24, 1904. Application filed November 18, 1903.

The process consists in hardening pure metallic oxides or pure metallic powders, to which no foreign additions, however, have been made, by means of chlorine compounds of whatever metal is used. For instance, oxide of copper is stirred to a fairly consistent paste in a solution of protochloride of copper and fine copper filings are stirred in. This paste is put into molds and heated for about half an hour to 100° C. Then the plate is electrolyzed with the object of setting free the oxygen and chlorine. It is claimed that such an electrode does not dissolve in alkaline solutions.

Exciting Fluid for Electrical Batteries.—G. F. Atwood, Wakefield, Mass. Patents 761,641 and 761,649, June 7, 1904. Applications filed October 3, 1903.

The inventor claims in the first patent a composition for use in the cell of electrical batteries, in which the negative or zinc element is immersed, consisting of ammonium carbonate 1½ pounds, carbonate of sodium 10 ounces, bisulphate of mercury 10 ounces, and sufficient sulphuric acid to make the specific gravity of 30 gallons of water 1.2. The second patent covers a composition for use in the cell of electrical batteries, in which the positive element is immersed, consisting of nitrate of sodium 7 pounds, nitric acid 142 pounds and sufficient sulphuric acid to make the spec. gr. of fourteen gallons of water 1.2.

Electrical Battery.—J. R. Lord, San Francisco. Patent 762,425, June 14, 1904. Application filed June 5, 1903.

The principle of this battery is the employment of a compound of the anode metal as the active anode material and the replenishing of the latter in such a manner that it is constantly precipitated upon the anode from the electrolyte. The illustrations show a form of cell, presumably rectangular, with the anode on the bottom and above it, in a horizontal position, the cathode. The general claim is for an electric battery having an anode composed of an electrical conductor upon or around which is placed or deposited a quantity of a compound of an anode metal, such conductor serving as negative pole and being placed in such a position that any solids chemically precipitated from the electrolyte may fall in proximity thereto, such solids thereby forming anode active material; having an electrolyte composed of one or more salts of one or more anode metals in solution; and having a cathode composed of any conducting substance chemically unattacked by the electrolyte.

Electric Battery.—J. E. Haschke, Chicago. Patent 762,715, June 14, 1904. Application filed February 8, 1904.

The construction of the battery shows a metallic receptacle which contains a series of cells. The latter are made up of unipolar negative-pole plates, which constitute the outside-end plates of the first and the last cells of the series, bipolar active plates, which separate the cells from each other, and a number of supplemental plates of alternating polarity in each cell. Provision is made to get the individual cells liquid tight, and the series is held together by tie-rods and nuts. The supplemental plates are preferably shorter than the cells and perforated, in order to allow the free circulation of the electrolyte. The principle can be applied to primary or reversible cells.

Miscellaneous.

Method of Purifying Water.—V. M. George, Youngstown, O. —Patent 761,044, May 24, 1904. Application filed January 8, 1904.

The method consists in passing the water through an apparatus where it is subjected to electrolysis, thence through a filtering vessel filled with a layer of tripoli as filtering material and finally through an ozonizing tank. The apparatus for electrolyzing comprises a tank, in which are arranged four plates nearly square or rectangular. The lowest is made of copper, the next of an aluminium-nickel alloy, the third of zinc and the fourth of carbon. The plates of carbon and of aluminium-nickel are connected to one pole, the zinc and copper plates to the other of the source of current.

Clarifying and Filtering Apparatus.—D. L. Watson, New Orleans. Patent 761,187, May 31, 1904. Application filed October 2, 1903.

The apparatus comprises four cylindrical tanks disposed within a larger tank. The first one of these tanks contains an electrolyzer, disposed on both sides of a partition, which reaches nearly to the bottom of the tank and forces the water to travel downward on one side of the tank and upwards on the other side. It is thus twice subjected to the influence of the current. From the first tank it passes into the second, where it encounters a filtering body of charcoal, sand and quartz, after passing which it is led into the third tank, where it has to pass another filtering body of stone. It is then discharged into the large containing tank, ready for use. The fourth tank serves for the introduction of ice or any other suitable cooling agent. The electrolyzers are constructed of a horizontal frame of marble, provided with grooves, in which plates of platinum or other suitable material are seated. Alternate plates are connected with the positive and the negative poles of a source of current.

Explosive Cartridge.—Giovanni Cornara, Mantova, Italy. Patent 762,229, June 7, 1904. Application filed December 31, 1897.

The cartridge is formed of an outside reservoir, strong enough to stand the pressure exerted by the gases generated within, which serves at the same time as cathode. The electrolyte is a 5 per cent solution of caustic potash or soda. An anode is introduced insulated into the reservoir and the solution is electrolyzed with a current not exceeding 7 amperes per square decimeter of anode surface. The gases resulting from the electrolysis are exploded by means of a cap, a fuse, or a metallic wire rendered incandescent by the passage of an electric current.

SYNOPSIS OF ARTICLES IN OTHER JOURNALS

A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.

Industrial Electrochemistry.

Cyanide Process.—The *Engineering and Mining Journal* of May 5, contains an article by C. M. Fassett on the Hendryx electrocyanide process, for which the following claims are made; that it is applicable to any ore, the values of which are soluble in cyanide solution or which can be made so by preliminary treatment; that extraction and deposition of the gold and silver are carried on simultaneously; that the extraction can be made in much less time and with less amount of chemicals than by the old processes, on account of perfect agitation, the aeration and regeneration of cyanide by the electric current. No special qualifications are said to be required in the crushing machinery. "The more slime the better." The process is stated to be adapted to handling tailings and slimes from metal-

lurgical plants already equipped and running. The first cost of installation and the cost of operation are stated to be small. The process is described as follows:

The ore is crushed (preferably in a dilute cyanide solution) and run into the agitator, together with enough alkali to overcome the acidity of the ore, and enough cyanide to bring the strength of the solution up to about 1 pound per ton. The bulk of the solution used is from one to two times the weight of the dry ore. The charge is then agitated, and as the precious metals are dissolved, they are deposited on the plates in metallic form, by the agency of an electric current of low intensity furnished by a small dynamo. As soon as the assays show that the extraction is complete, a valve is opened in the bottom of the agitator, and the charge runs into a settling tank, whence the settled pulp is sluiced to waste and the clear solution

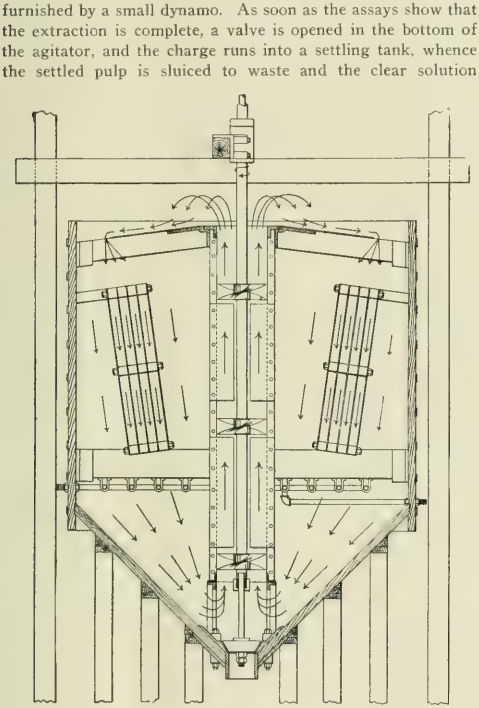


FIG. 1. AGITATOR FOR CYANIDE PROCESS

pumped back to storage. The essential mechanical feature is the agitator illustrated in Fig. 1. It consists of a cylindrical tank having a conical bottom of 45° pitch. In the center of the tank is a circular well, which extends nearly to the top and bottom, supported by braces from the sides of the tank, and having a circular apron at the top which slopes gradually toward the circumference. In this well is a hollow shaft, carrying a driving pulley at the top and three screw propellers in the well. The discharge valve is connected to a valve stem which passes through the hollow shaft and is operated by a hand wheel located above the driving pulley. Outside the well, and between the apron and the bottom of the tank, the anode and cathode plates are supported from the sides of the tank and supplied with the electric current. A coil of pipe serves for raising the temperature of the charge by means of steam or hot water passed through it. The revolution of the propellers in the well produces a strong upward current there and results in a rapid and uniform circulation of the whole charge upward through the well and downward among the electrically charged plates, as indicated by the arrows in the drawing. It appears that an experimental plant in the author's laboratory has been working for six months successfully, but that the process has not yet been applied on a large scale.

Electro-Magnetic Concentration of Iron Ore.—The utilization of low-grade magnetic iron ores is practically dependent on magnetic concentration. In the United States this concentration is practised on a large scale, followed frequently by briquetting, using lime as a binder. The Gröndal process, as used at Herräng, Sweden, consists in briquetting by pressure alone, then roasting to a hard brick. The ores at Herräng, according to a paper of H. LOUIS, before the *Iron and Steel Institute*, carry 1 to 1.5 per cent sulphur, and when the briquetted concentrates are roasted at about 1300° C. the sulphur is expelled, and the ore converted largely into ferric oxide and agglutinated into very strong briquettes. This roasting is done in a tube 145 feet long, the briquettes taking twenty-four hours to pass through; the fuel used is blast-furnace gas, and the power for the crushers and separators is also obtained from the same source, using gas-engines. The blast-furnace thus furnishes the means of preparing the ore, when its gases are properly utilized.

A fully illustrated article by C. Q. PAYNE in the *Engineering and Mining Journal* of June 23, gives an account of the magnetic concentration of zinc ore in various mines of Virginia. The schemes of the treatment in use at the Withe mine, and at the Delton mill of the Clark mine, are described and illustrated by diagrams. At the latter mill four magnetic separators are arranged, tandem in pairs, the first pair producing a rough zinc concentrate and clean iron tailings, while the second pair, which retreats the rough zinc concentrate, produces therefrom a clean concentrate and a certain amount of middlings, which are repassed over the first set of machines. These separators were designed by the author and the design is based on the fact that in the separation of feebly magnetic minerals, such as limonite, garnet, etc., a very powerful or dense magnetic field is not so important as one in which the position of the lines of force are so controlled that great differences of magnetic density are established therein. The design of the separators is described and illustrated.

Explosions Produced by Ferro-Silicon.—Additional information concerning the explosions of casks containing ferro-silicon, at Liverpool, was given by A. DUPRE in a communication to the *Iron and Steel Institute*, on May 5 last. The material causing the explosions contained silicon 59.40 per cent, iron 36.85, manganese 0.08, aluminium 2.73, calcium 0.14, magnesium 0.17, carbon 0.218, sulphur trace, phosphorus 0.056 per cent. The gas from a cask was analysed and showed hydrogen phosphide and hydrogen arsenide, and it is to the former that M. Dupre ascribes the explosions, stating that experiment has shown that 4 kilograms of powdered ferro-silicon would make 64 liters of air explosive. The precautions suggested were to fill up the drums with paraffin oil of high flash point, or to ship only solid ingots, well tarred and tightly packed. In the discussion, Mr. Watson Gray stated that 25 per cent and 75 per cent ferro-silicon did not disintegrate, but that the 50 per cent quality did, even if dipped in paraffin wax to keep out moisture. Calcium was not the cause of this, since 40 per cent ferro-calcium is quite permanent, even in damp air. Mr. J. E. Stead attributed the disintegration to calcium phosphide, which is soluble in melted ferro-silicon and is excluded as an envelope around each crystal as the mass sets. Professor Le Chatelier thought that the calcium silicide present produced hydrogen silicide, which was spontaneously inflammable. The paper and discussion are highly interesting to electrometallurgists.

Electrolytic Preparation of Chloroform from Acetone.—The May issue of the *Journal of the American Chemical Society* contains a paper by J. E. TEEPLE, showing that his recent method for electrolytically preparing iodoform may also be applied to the production of chloroform. From his former work the following scheme suggested itself; electrolysis of a chloride solution in the presence of acetone under conditions which would continuously give the greatest possible yield of hypochlorite, *i. e.*, at a temperature below 25° C., with a solution

containing no alkali or as little as possible, with a high current density at the cathode, and a comparatively low one at the anode. The following arrangement of the experiments may be used. In an ordinary cylinder of 150 to 200 cc capacity, 100 cc. of water are placed, with 20 grams NaCl and 4 cc. acetone. A platinum cylinder serves as anode and a platinum wire as cathode. The vessel is closed with a cock connected with a reflux condenser and the apparatus is cooled with running water. During electrolysis a slow stream of chlorine is passed, as needed to neutralize the alkali. The anode current density is about 6 amperes per square decimeter or less. After 8 to 10 ampere-hours a small layer of chloroform may be removed from the bottom of the electrolyte by a pipette and more may be obtained by distilling the solution with steam. The amount of chloroform thus obtained, does not represent the whole current action in that direction, nor is it the whole of the chloroform actually formed, for a considerable part is still held in solution by the acetone; but if the process were run continuously on an industrial scale, there would be no loss from either of these sources.

Electrolytic Preparation of Bromoform.—In an article published in *Zeit f Elektrochemie*, June 17, E. Mueller and R. Loebe describe a similar method for preparing bromoform by electrolysis of solution of potassium bromide in presence of acetone. Coughlin had developed such a method in which he used a diaphragm cell. He used in the anodic compartment a solution of 25 grams KBr 10 cc. acetone and 75 cc. water. During electrolysis, which was carried out at about 25° C, with an anodic current density of 0.04 ampere per square centimeter, gradually 3 grams of sodium carbonate were added. The cathodic compartment contained a solution of 10 grams of sodium carbonate in 100 cc. water. The present authors have found that it is not necessary to use a diaphragm, if special means are applied to prevent reduction at the cathode. For this purpose chromate is added to the electrolyte; the addition of chromate has been applied by Mueller for similar purposes before. During electrolysis a current of carbonic acid is passed through the electrolyte. Good results were obtained, for instance, with the following arrangement. A glass beaker was filled with 140 cc. of a 25-per-cent solution of potassium bromide to which was added 0.02 per cent potassium chromate; also 20 cc. of acetone and 20 grams of solid potassium chromate. A platinum sheet of 30 square centimeters surface was used as anode, and a spiral platinum wire as cathode. The current was 2 amperes and carbonic acid was passed through the solution. The temperature was 15° C. At the end of the experiment 20.58 grams of bromoform had been obtained, corresponding to an ampere-hour efficiency of 90.2 per cent.

Diaphragm Cells for Electrolysis of Sodium Chloride.—The *Journal de Chimie Physique* of March, April and May contains a long paper by A. Tardy and P. A. Guye on diaphragm cells for the electrolytic production of caustic soda and bleaching powder. The experimenters used a greater number of diaphragms of different make, and found that in order to define the action of a diaphragm it is necessary to make two measurements; the first is a measurement of the porosity and the dimensions of the diaphragm, the second a measurement of its (mechanical) permeability. These two measurements may be supplemented advantageously by a diffusion experiment. The first two experiments are made with water, the third one with an electrolyte with a known coefficient of diffusion. By means of these measurements it is possible to give at once those quantities which represent characteristc features of the nature of the diaphragm. The authors distinguish five characteristic features of a diaphragm and show how, on the basis of the above measurements, numerical values can be derived for these characteristic features. A longer abstract of the paper will be given in our next issue in a separte article.

Fixation of Atmospheric Nitrogen.—This subject, which has aroused special interest on account of the experimental trial on a large scale by the Atmospheric Products Company at Niagara Falls, has also attracted other inventors. Some references are herewith given to recent papers. An investigation by Muthmann and Hofer is found in *Ber. D. Chem. Ges.*, 1903, 2, 438, and an investigation by Rasch in Dingler's *Polyt. J.*, 1903, 17, and a paper by C. Brandt in *Rev. Gen. Ch. Pure. et Appl.*, 1903, page 517. The latter author proposes to use electrostatic machines, furnishing directly oscillatory discharges at high potentials. A paper by von Lepel is published in *Ber. D. Chem. Ges.*, vol. 37, page 712, March 12, 1904. He discusses the relation between arc, temperature and output of nitric oxide by electric discharges through air. He made experiments with a rotating anode. The output is increased by impregnation of the cathode with certain salts. For instance, other things being equal, *i. e.*, with equal speed of rotation, and at the same temperature, he obtained 64 mg HNO_3 if the cathode was wetted with water, against 126 mg if it was wetted with KOH.

Copper.—Metallurgie of June 8 contains a long illustrated article on copper mining and treatment on the works of the Mansfeld district in Germany. These mines have been worked since the year 1200, but the greatest extensions were made during the last 50 years. The output of copper was 18,749 tons in 1902 (against 1,485 in 1861), that of silver 98,445 kg. (against 8,008) and the number of workingmen 19,883 (against 4,677). The article contains a great amount of statistical information on the development of the works. In connection with the works there is an electrolytic refinery which is supplied with power partly from two gas-driven generating sets, each of 120 hp., utilizing blast furnace gases.

Theoretical and Experimental.

Silver Voltameter.—With the ordinary type of silver voltameter the results so far obtained have been not quite satisfactory. T. W. Richards has pointed out that the main trouble arises from the formation of a complex ion at the anode which, when transported to the cathode, will deposit too much silver. To prevent the anode liquid from reaching the cathode, he surrounds the anode, which is a silver rod, by a porous fine-grained cup, and keeps the level of the electrolyte in this cup always lower than that of the outside. Leduc, on the other hand, hopes to prevent the formation of the disturbing ion by using a very small current density at the anode; he therefore employs as anode a mass of the granulated silver surrounded by filter paper. In an American Physical Society paper which is abstracted in the June issue of the *Physical Review*, K. E. Guthe describes a series of experiments which were made to compare the different forms of the silver voltameter in a severe test. He finds that the usual type of silver voltameter is not a very reliable instrument for measuring quantity of electricity. Leduc's type does not prevent the formation of the complex ion even with a small anode current density; the use of filter paper should be avoided. Silver in contact with the anode liquid breaks up the complex ion. Richards' type is the only satisfactory form so far proposed, and gives very consistent results. For convenience in manipulation, Guthe has modified it in such a way as to avoid the necessity of removing, by frequent pipetting, the anode liquid from the bottom of the porous cups. Finely divided silver is placed at the bottom of the cup and this effectively removes the complex ion. In order to insure a constant resistance of the voltameter it was found necessary to surround the lower part of the porous cup by a small glass beaker. A second type proposed by Guthe is the large silver anode voltameter; granulated silver is placed in a layer about 0.5 cm. deep at the bottom of a large porous cup; upon this is pressed the silver plate forming the anode connection. The whole is immersed into the platinum bowl (the cathode), containing a neutral 20 per cent solution of silver nitrate. In an extended series of tests in which currents ranging from 0.2 to 1.5 amperes

were employed, the results obtained with the Richards type, and with the two types designed by the author, were very consistent, the largest variation of any single value from the mean not exceeding one in 20,000, except when a current of only 0.2 ampere was used.

Mobility of Ions in Liquid Ammonia Solutions.—The May issue of the *Journal of the American Chemical Society* contains a paper by E. C. FRANKLIN and H. P. CADY, giving the results of an extended investigation of ionic mobilities in liquid ammonia solutions. The authors have developed an apparatus which is essentially an improvement and modification of the method of Lodge and Masson for determining the mobility of ions directly by observing the movement of a colored boundary surface. They determine the velocities of a number of univalent ions in liquid ammonia at — 33° C. These were found to be 2.4 to 2.8 times as great as they are in aqueous solutions at 18° and the values were found to be in agreement with the velocities calculated from conductivity measurements by the method of Kohlrausch.

Copper Analysis.—A rapid and convenient method for the quantitative electrolytic precipitation of copper is described by T. W. RICHARDS and H. BISBEE in the May issue of the *Journal of the American Chemical Society*. The consideration of the conditions necessary for a quick quantitative electrolytic precipitation shows that among the essential ones are the concentration of the solution and the area of the electrode. In the method described by the authors, these conditions are made as favorable as possible by concentrating the electrolyte and placing it between two large surfaces in a thin film, such as the annular space between two crucibles separated by a tripod like device of thin glass rods. As the concentration of the electrolyte diminishes during electrolysis, the current strength is diminished, either in steps by the operator or automatically by employing a single storage cell with resistance. The time required for complete precipitation is inversely proportional to the concentration of the solution if the cathode surface is unchanged.

Semipermeable Diaphragm.—In an article published in *Zeit. f. Elektrochemie*, May 13, J. SEBOR deals with the speed of diffusion of water through a semipermeable diaphragm. The speed of diffusion is nearly directly proportional to the osmotic pressure of the dissolved substance, so that there might be a possibility to use such a method for determining osmotic pressure, etc. The speed of diffusion decreases with the temperature.

Electrolytic Analysis.—In two articles published in the *Zeit. f. Elektrochemie*, June 3, L. AMBERG discusses the use of revolving electrodes for decreasing the time required for electrolytic analysis and gives some notes on the electrolytic deposition of palladium.

BATTERIES.

Edison Alkaline Battery.—Electrical World and Engineer of May 7 contains a longer abstract of R. A. FLIESS' paper, which was noticed on page 169 of our May issue.

Jungner Battery.—A shorter communication by M. U. SCHOOP in *Elek. Zeit.*, May 26, and a longer article by the same author in *Centralblatt f. Accum.*, June 15, deal with the history of the Jungner accumulator and the question of priority between Edison and Jungner. In the former communication Schoop says it is unfair to use his experiments with an old Jungner nickel-cadmium cell (ELECTROCHEMICAL INDUSTRY, September, 1903, page 465) to make comparisons with the Edison battery, since his former article referred rather to the theory of the alkaline accumulator. "Dr. Jungner knew very well the weak points of his nickel-cadmium and nickel-iron cells which had been made with unsufficient means and machines. For this reason he has not placed his cells on the market. On the other hand, Dr. Jungner is justified in claiming the priority of having invented the alkaline accumulator with constant electrolyte." In the article in the *Centralblatt* Schoop gives a long review of the history of the subject. Jungner began to work along these lines in 1892; he started from the old copper-zinc combination in alkaline solution and tried oxide of copper as one electrode against many different metals as the other; to increase the conductivity of the active masses he added powdered graphite (English patent, October 23, 1895); in 1896 he embedded his active materials between perforated metallic plates (English patent of 1897). The data of Jungner's Swedish patent for the nickel-iron combination is January 29, 1901; he gives there the following formula for the reaction during discharge:

$$NiO_2 + 2Fe(OH)_2 + H_2O = NiO + 2Fe(OH)_3;$$

Schoop emphasizes that he and Jungner are convinced that if a comparison is made between the alkaline accumulator and the lead accumulator concerning the cost of manufacture on the basis of watt-hours per unit of weight, the cost of the nickel-iron cell is certainly not higher than that of the lead cell; the active iron material can be made by a very simple and cheap method and this fact counterbalances the higher cost of the nickel. Schoop's article is concluded as follows: "Between Jungner's invention and that of Faure there is a certain obvious analogy, in so far as Faure's patent 19,026, of February, 1881, which was of greatest and decisive importance for the manufacture of lead accumulators, protected to a certain extent the general principle of making lead accumulators of high capacity in a short time. In his patent specification C. A. Faure had given detailed instructions for the manufacture and formation of the active materials, and for the use of porous diaphragms. Nevertheless, it is well known that nobody has succeeded in making commercially satisfactory lead cells on the basis of nothing but Faure's instructions; this became possible only by the use of a grid as support of the active material; this had not been provided for by Faure. But the principle, on the basis of which lead cells with high capacity could be made in a short time, was given in Faure's patent, and every manufacturer who wanted to apply a quick formation—*i. e.*, not according to Planté—was obliged to recognize Faure's patent."

(Mr. Schoop is the chief engineer of the German storage battery manufacturing concern, which has bought Dr. Jungner's German patents.)

MISCELLANEOUS.

The Thermal Efficiency of the Blast Furnace is a subject interesting to any one having to do with furnaces, be they fuel or electric in their nature, and Mr. W. J. FOSTER presented to the *Iron and Steel Institute* recently the results of the most thorough investigation which has been made in this direction since I. Lowthian Bell's classical researches. The data are too copious to be reproduced in abstract, but show practiacly 50 per cent of the calorific power of the fuel to be contained in the gases as combustible power, 15 per cent to be absorbed in reductions, and 15 per cent to exist as sensible heat in the pig iron, slag and gases. Electrometallurgists will find food for reflection in making comparison with the thermal efficiency of electric furnaces, such as calculated by Dr. J. W. Richards (this journal, October, 1902, page 46), and the comparison is to the advantage of the latter, as far as utilizing available heat producing power is concerned.

The Melting Points of Iron Carbon Alloys is an interesting field which has been recently reported upon by Messrs. CARPENTER and KEELING, before the *Iron and Steel Institute*. The temperatures were measured by thermo-electric junctions, calibrated by direct comparison with the nitrogen thermometer up to 1000° C., and extrapolated above. Thirty-eight alloys were made by melting Swedish charcoal iron with wood charcoal, and it is believed that the melting points were determined to within 5° C. The beginning of solidification was found to be, for pure iron, 1505° C.; with carbon 1 per cent, 1444°; carbon 2 per cent, 1368°; carbon 3 per cent, 1278°; carbon 4 per cent, 1173°; saturated at 4.3 per cent, 1139°. The results are represented by the equation $t = 1505 - 54.65\ C. - 7.1\ C^2$, wherein C is the percentage of carbon. It will be noted with surprise that while the first one per cent of carbon lowers the

melting point of iron 61°, the fourth per cent lowers it 105°. This method of stating the result is, however, not strictly accurate scientifically, since the effect of equal increments of carbon on a fixed amount of iron should be the basis of comparison, and not upon a regularly decreasing quantity. If the data given by Messrs. Carpenter and Keeling are reliable, however, it must be true that the fourth increment of carbon is more powerful than the first, in lowering the melting point, and our physical chemists have a very stubborn "why?" to overcome. The final part of the paper dealt with the critical points of these alloys, and confirmed in general the outlines of the Roozeboom diagram, which is familiar to all students of the physics of iron and steel.

Pyrometers Suitable for Metallurgical Work.—The *Iron and Steel Institute* gave a half-day, at its recent spring meeting, to the inspection and discussion of various pyrometers. Thirteen different instruments were exhibited, the only new ones being the Zaubitz pyrometer, whose construction was not described, and the Baird and Tatlock pyrometer, which latter has two opposed thermo-junctions. The Le Chatelier and the Nehling are stated to be in wide use in England. In the discussion, Prof. T. Turner, of Birmingham, described a novel means of determining melting points. The substance is placed on a piece of fireclay along with several pieces of metals of higher and lower melting points, the whole is put into a muffle, the gas lit and times taken by a stop-watch. The melting points of the metals are plotted on cross-section paper, as ordinates, with the times at which they melt as abscissæ, and a smooth curve drawn through these. The time at which the unknown substance melted being noted, its melting point is found on the curve. The advantages of this method are that it depends only on having pure metals of known melting points, and that the higher temperatures are not crowded together, but rather drawn apart by the method used. Mr. Gledhill recommended the Siemens water pyrometer, using an iron ball, as most suitable for determining the temperature of armor plate in a furnace. This is also the experience of a large American steel works, which has tried all other forms of pyrometers.

Chemical Application of N-Rays.—The latest kind of radiations which have been examined during recent years—the so-called N-rays—have been found by A. Colson to be given off during certain chemical reactions and their occurrence can be utilized as a physical criterion for such reactions. His paper is published in *Comptes Rendus* of May 2, and abstracted in London *Electrician*, May 20. The chemical reactions which give rise to N-rays are invariably accompanied by some physical action such as contraction. Some very vivid chemical reactions, like the precipitation of salts, are not accompanied by any evolution of N-rays, so that there is evidently no proportionality between the chemical reaction and the evolution of N-rays. It is just this lack of proportionality which makes the N-rays valuable to the chemist, since he is thus enabled to discover reactions which may be masked by other more evident chemical reactions. A solution of aluminium sulphate mixed with a saturated solution of potassium sulphate at the ordinary temperature gives out neither N-rays nor N′-rays, but if the supersaturation of the alum whose elements are found in the solution is made to cease, N′-rays appear. Similarly, sodium sulphate in a supersaturated solution gives off N′-rays when the supersaturation is stopped by the addition of a crystal and the radiation ceases when the crystals are all deposited. Powdered chrome alum, thrown into cold water, increases the brightness of the calcium sulphide screen, while the violet solution is being formed. But if boiling water is used and the solution is rapid, the emission of N′-rays is such that the luminosity of the sulphide disappears almost completely. Thus the solution of chrome alum leads to the emission of N-ray, while its decomposition by hot water leads to the emission of N′-rays.

RECENT METALLURGICAL PATENTS.

Manufacture of Silica Tubes.

The manufacture of chemical apparatus from "vitrified quartz" has attracted the interest of various experimenters during recent years, on account of the exceedingly small coefficient of expansion, the high melting point and the very great resistivity of such articles against sudden temperature changes. The manufacture of articles from silica meets, however, with very great difficulties. On account of the exceedingly high temperature required, either the oxyhydrogen flame or the electric arc has been applied, the former, for instance, by Heræus, who has made chemical apparatus of quartz of various forms or sizes, (Electrochemical Industry, vol. I. pages 366, 586), while experiments made with the electric arc were described by R. S. Hutton in an American Electrochemical Society paper (Electrochemical Industry, vol. I., page 58).

An interesting method of making silica tubes or other hollow articles has now been patented by Elihu Thomson (Patent 761,111, May 31). He also utilizes the heat of the electric arc. At the start of manufacture the ends of two carbon rods of suitable cross-section, forming the electrodes, are in contact. Pulverized quartz is placed around the rods. The electrodes are then slowly removed from each other, drawing a gradually lengthening arc and thereby producing a progressive fusion of the quartz next to the electrode surface. As the arc lengthens, a tube of quartz is formed. When completed, this tube is mounted upon a carbon rod and inserted in the flame of an arc; thereby a fusion and compacting of the exterior surface of the tube is produced so as to render it smooth.

Gold.

A combination of electrolysis with the chlorination process for gold extraction from ores is patented by W. E. Greenawalt (761,164, May 31). By electrolysis of salt water chlorine is produced at the anode; it is exhausted from the electrolyzing cell and conveyed into the scrubbing tower, where, coming in contact with water in a state of subdivision a saturated solution of chlorine is obtained, which flows into a storage tank. The barrel, used for leaching, is then charged with ore and solution, and revolved for a short time, say about one hour. During this time much or most of the chlorine has been consumed by satisfying the base elements in the ore. The old solution in the barrel is then displaced by a fresh quantity of new solution under pressure and the barrel is again revolved to extract the precious metals. An illustrated description of the Greenawalt plant at the Wallstreet Mills in Colorado was given in Electrochemical Industry, January, 1904, page 24.

P. Danckwardt (760,429, May 24) patents a filter for extracting valuable metals, such as gold, silver, copper, zinc, etc., from low-grade ores or slimes that cannot be leached in an ordinary tank with a heavy layer of ore, or which require such fine grinding that leaching from a tank becomes an impossibility, and for which the present processes in use, viz., those by decantation of filter-presses or suspended filters, are too expensive. His filter is composed of a series of shells, arranged on successively-lower levels, with inclosed filtering chambers. Pipes connect the bottoms of the shells with the

tops of the next lower shells. Solvent pipes enter the bottom of the shells and suction pipes enter the filtering chambers.

NICKEL.

Mond has formerly described the following process for recovering nickel from its ores. The ore is calcined, so as to get it into the condition of an oxide; the oxide is reduced by the action of reducing gases, like water gas; the spongy nickel metal thus obtained is treated with carbonic oxide, producing a compound vapor, mixed with an excess of carbonic oxide and called by Mond "nickel carbon oxide," but now generally known as "nickel carbonyl." This substance can be separated as a liquid, which, on being heated, vaporizes and becomes decomposed, the carbonic oxide being liberated and pure nickel being decomposed as coherent metal.

James Dewar (760,852, May 24) remarks that the nickel carbonyl vapor at ordinary pressures is very unstable, its components becoming rapidly dissociated with explosion on moderate elevation of temperature, so that its production has hitherto been carried on at a moderately low temperature, such as 50° C. Dewar has found that under considerable pressure, ranging from 2 atmospheres to 100 atmospheres, the compound, either as vapor or as liquid, is much more stable, and therefore higher temperatures can be used in its production, whereby the rapidity of process of manufacture is greatly increased. Thus for the gasification of the nickel a temperature of 100° C., with a pressure of 15 atmospheres is suitable, or a temperature of 180° C., with a pressure of 80 atmospheres. The spongy nickel obtained by the reduction by means of water gas, if treated at the temperature and pressure mentioned, combines rapidly with the carbonic oxide, producing vapor of nickel carbonyl. This vapor, with the excess of carbonic oxide in which it is diffused while still under pressure, on being passed through tubes of a higher temperature, becomes dissociated depositing metallic nickel, while the separate and diluent carbonic oxide can be returned to act on the fresh charges of spongy nickel.

ALUMINIUM.

C. Ellis (760,783, May 24) patents a flux for soldering aluminium, "consisting of a heavy metal salt whose heat of formation is less than the corresponding salt of aluminium, a saline body whose heat of formation is greater than the corresponding salt of aluminium and an organic body." As an example is given a mixture of 10 parts of silver bromide, 9 parts of sodium fluoride and 25 parts of melted wax. The mixture is stirred until the solidifying point is nearly reached, when the plastic mass may be moulded into the form of sticks or pencils. If the mixture is to be applied in paste form, a solvent may be added, such as turpentine, alcohol or paraffin oil.

ROASTING FURNACES.

Franz Meyer (761,691, June 7) patents a muffle-roasting-furnace which comprises a series of roasting chambers. Each is formed as a separate unitary structure, effectively braced and anchored against the disrupting effects of expansion by means of an enclosing metallic shell, lined with refractory material. A heating furnace is common to the series of roasting chambers. Suitable flue connections are provided, with expansion joints between the successive chambers of the series, and means for preheating the air for oxidizing the sulphur in the ore.

C. C. Wilson (760,941, May 24) patents a revoluble cylindrical ore-roasting and automatic ore-feeding and rabbling furnace. From the walls of the revoluble ore-roasting chamber project longitudinal shelves constructed to cause the ore to drop from shelf to shelf and to move inwardly and outwardly on the opposite side of each shell.

A. A. Bean (761,646, June 7) patents a revolving cylindrical return-flue furnace. It contains three horizontal concentric cylinders, providing two compartments with annular cross-section and one with circular cross-section. The combustion and smoke chambers are connected to the opposite ends of the outer and inner compartments. The ore is fed into, conveyed through, and discharged from the middle compartments, while means are provided for introducing air and steam into the middle compartment, and for rotating it.

W. H. Smyth (761,049 and 761,050, May 24) patents an ore-roasting furnace whereby the rabble-carrying and operating mechanism is carried entirely outside of the furnace and thus is protected from heat and destructive gases of the furnace. In his multiple-hearth furnace he uses a plurality of superimposed slotted-hearth furnaces, rabbles adapted to travel above the hearths, to stir the ore thereon. Travelling bands effect the travel of the rabbles or stirrers, the parallel stretches of which travel in the same vertical plane. The slots are closed by flexible overlapping plates.

MELTING FURNACE.

J. Southern (760,495, May 24) patents a furnace for melting metals. The heavy thick front wall of the furnace is built of brick and provided with apertures or combustion-chambers which extend from front to rear. The middle portion of these chambers is enlarged and their further ends branch into a greater number of openings to discharge heat into the melting chambe·

MISCELLANEOUS METALLURGICAL APPARATUS AND APPLIANCES.

J. Kennedy (760,873, May 24) patents details of construction of hot-blast valves in which the valve seat is gripped between two sections of the valve casing. The patent refers especially to the methods of gripping and releasing the valve-seat.

W. H. Hume (762,721, June 14) patents details of construction of reversing valves, used to regulate and control both the flow of gas and air to a Siemens regenerative furnace, and the discharge of the spent gas into the stack. He endeavors to eliminate any feature of mechanical nature For this purpose he provides a chamber with two separate open compartments upon its floor, a passage from the chamber to the furnace, an inlet-passage for gas or air extending down into one of the open compartments, an exit passage for spent gas extending down into the other open compartment, and water in the two separate open compartments for alternate action upon the open ends of the inlet and exit passages to regulate and control the flow of gas and air and the discharge of spent gas.

A. Kurzwernhart (760,633, May 24) endeavors to prevent the loss of gas on reversing the controlling valve in a Siemens regenerative furnace. Before the reversing operation, the gas contained in the regenerative chamber and in the passages connected therewith is forced into the furnace by air which, after the gas has been cut off in a known manner, is introduced through a lateral opening.

N. J. Norman (761,900, June 7) patents a welding flux for welding two pieces of copper or metals. It is formed of the following ingredients in pulverized form; 4 parts sal-ammoniac, 3 parts saltpeter, 3 parts sal-soda, 4 parts yellow prussiate potash, 5 parts borax and 3 parts pulverized glass.

The casting of slag or cinder from blast furnaces into the form of brick or building block has proven a useful and remunerative way of disposing of this by-product. E. A. Uehling (760,825, May 24) describes a device in which the moulding of the brick and its annealing is carried out at one and the same time. The bricks are annealed by means of their own latent heat and the method is claimed to be rapid and economical.

H. L. Gantt (762,301, June 14) describes a forge furnace which affords a high temperature, and in which the tools or other articles to be heated need not be placed in contact with the fuel, but in a specially provided chamber.

M. Slotkin (762,005 June 7) provides a foot-power mechanism for driving the fan of small forges, so that both hands are free for holding and manipulating the article in the forge.

W. J. Newton, R. Diggle and G. Watson (763,199, June 21) patent details of construction of dust arresters in order to provide an automatic and effective means for arresting or pre-

venting the escape of dust or the like from refuse burners or other furnaces and flues, the arrangement being made that the accumulated matter may be removed without interfering with the furnace draft.

F. W. Shupert, J. Wormald and H. L. Shupert (761,418, May 31) patent details of construction of the arches in the fire-boxes of locomotive engines. They use a body portion of baked fire clay with an internal strengthening structure composed of iron rods with asbestos covers.

Correspondence.

THE CHEMICAL ENGINEER.

To the Editor of Electrochemical Industry:

Sir—Considering the source from which it emanated, and the ripeness of the time for the agitation, it is not surprising that the paper delivered by Mr. J. B. F. Herreshoff, before the American Chemical Society on the "chemical engineer," (Electrochemical Industry, May, 1904) has attracted wide notice by abstraction, and excited much discussion at the time of its presentation.

The value of an engineering training, supplementary to the usual technical equipment of a chemical graduate, is obvious, and the matter at once resolves itself into a consideration of the most advantageous course for a young man to pursue in order to fit himself for tackling industrial chemical problems. The figures quoted in the early part of Mr. Herreshoff's paper plainly show the enormous proportions our chemical industry has attained, and it is farther true that the field wherein these operations are carried on contains a more varied and at the same time somewhat closely allied series of processes than those underlying any other single branch of commercial activity.

It would seem, therefore, as though the industry had reached that stage where our present educational system were inadequate to supply the demands of its vigorous advance, and the query very naturally arises whether the field is not large enough to accommodate two specifically trained classes of chemists, in addition to requiring on occasions the services of an engineer for problems clearly within his province.

In any event the trained analyst is a necessity. It is true that the educated "wash boy" becomes in time an economical and valuable member of the laboratory community, but he has his limitations, and it is doubtful in my mind whether his growing presence to the exclusion of college-trained men among the staff of an industrial laboratory is a wise policy.

The chemists which our colleges are yearly turning out, are more fitted for the analytical than for any other department of a chemical manufacturing establishment, and in many cases it is only too apparent that a recent graduate is incapable to manipulate with rapidity and accuracy required in a "works" laboratory.

Considering that nearly 75 per cent of the time spent upon chemical subjects in our university chemical courses is devoted to analytical work, and that this is scarcely adequate to produce a first class analyst, one of two conclusions is inevitable; that, first, a young man electing to connect himself with the manufacturing end of the chemical industry must be prepared to gain the necessary preliminary training after leaving college, or, secondly, that our universities must provide a course with the object of inculcating in the student the principles of chemical economics.

I am quite sure that it would puzzle the heads of many chemical departments to outline the daily routine for such a course, as on a number of occasions I have had an opportunity of remarking how completely out of touch the average chemical instructor is with the particulars of large scale operations. This condition is possibly in part due to the secrecy maintained by the majority of the manufacturers in this country. It is questionable, however, whether the various chemical plants contain valuable original processes or whether, as some one else has suggested, their dilapidated and inefficient state urges an exclusion of visitors.

However, be that as it may, it is a digression from the object of these lines, viz., to offer a few suggestions as to an alternate course in chemistry in our technical schools. It must be admitted that by virtue of the inherent differences between demonstrating a process and the operating of a plant where labor, location and cost of materials, etc., have such a direct bearing on the method followed, it is a different problem to arrange a course of work sufficiently comprehensive to be of material advantage to the student.

A great part of the work in quantitative analysis might be eliminated from the present course without working injury to the training of the future chemical engineer.

This change would place at our disposal say ten hours per week to be devoted to studies of a strictly technical bearing.

I used above the phrase, chemical economics, and if I do not mistake Mr. Herreshoff's idea this describes perhaps more accurately than "chemical engineering" the branch of the industry for which his plea was made. Here certainly is one phase of the problem of chemical manufacturing of which the young graduate is comparatively ignorant.

He naturally realizes that cheapness of production consistent with quality is the good to be sought, but his chemical education has not laid stress on certain economical principles governing the proper procedure in several operations common to many processes, *e. g.*, teaching absorption of gases by liquids, tower packing, mist condensation, etc. A theoretical consideration of such points would be of great value in preparing for an industrial career.

Next in importance I would rank a study of the economical significance of physico-chemical phenomena. While physical chemistry is at present a prominent factor in the usual chemical curriculum, it is doubtful whether the student has received a training that permits of practical application of the principles absorbed.

Electrochemical possibilities should by no means be neglected, and in this connection an opportunity should be taken advantage of to familiarize the student with the control of the electric current, and with electrical apparatus.

The transmission of power and the handling of material are of immense importance in a chemical factory, yet I venture to assert that the newly graduated chemist is quite unfamiliar with the various mechanical devices for these purposes, and would be therefore greatly handicapped in designing a simple plant, even were the chemistry involved perfectly clear to him.

Steam, the *sine qua non* of a chemical plant, is, so far as its economical and efficient use is concerned, a new friend to the chemical graduate.

One further subject, the choice of materials of construction, offers itself to most profitable and careful study, which now is altogether too lightly touched upon in the college courses.

A well-conducted training along these lines I have very briefly enumerated, I am convinced would save a man many months, and make a sound foundation from which to evolve the type of industrial chemist of which Mr. Herreshoff declared the need.

W. Murray Sanders.

Iola, Kansas.

Current Notes.

Revolutionary Character of Electrochemistry.—In commenting on Dr. J. W. Richards' last presidential address before the American Electrochemical Society, the *Engineering and Mining Journal* says, "The production of a half-ton of silicon at a moment when that element is listed as a rare chem-

ical at so many dollars per ounce, does indeed happily illustrate the revolutionary character of electrochemistry. The chemist is to the metallurgist what the prospector is to the mining engineer; he adventures into unknown territory and wins new country for exploitation; only in his case the greater scientific acumen is apt to be with the pioneer rather than the exploiter."

AMERICAN ELECTROCHEMICAL SOCIETY.—At the meeting of the Board of Directors, held on June 7, the following gentlemen were elected to membership: George Breed, Philadelphia, Pa.; Alexander Lodyguine, Staten Island, N. Y.; Charles Jackson, Guadalajara, Mexico. The dates of the St. Louis meeting were fixed for the 13th, 15th and 16th of September. On the 13th and 15th, joint sessions will be held with Sec. C. (Electrochemistry) of the Fifth International Electrical Congress, and on the 16th a joint session will be held with the Bunsen and Faraday Societies. Sessions will only be held in the morning. No session is being arranged for the 14th, as it is thought by officers of Sec. C. that if an independent meeting is set for the 16th, rather than the 14th, that the section may be through with its work by that time and be able to attend our session. Our members can in this way have the opportunity of attending the congress. At the next meeting of the Board of Directors, to be held on July 1, the names of the following gentlemen will come up for election to membership: H. E. Eggers, Santa Cruz, Cal.; George C. Hitchcock, Claremont, Cal.; F. L. Wadsworth, Morgantown, W. Va.; William C. L. Eglin, Philadelphia, Pa.; E. Humblot, San Francisco, Cal.; P. McN. Bennie, Niagara Falls N. Y.; J. W. Best, Denver, Col.

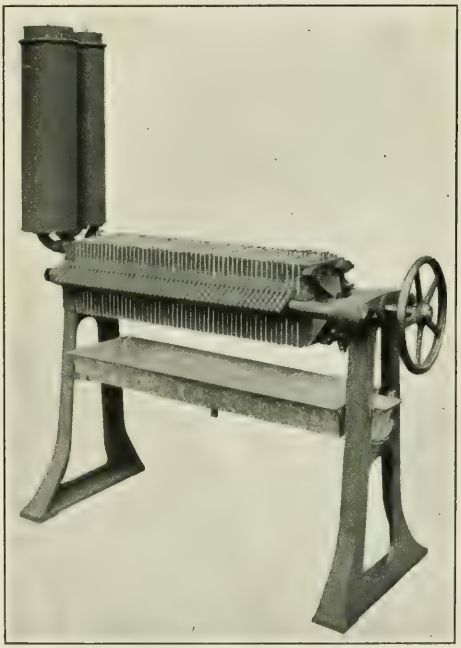
NEW USE FOR ALUMINIUM.—According to *La Métallurgie*, at a recent meeting of the "Société d'Encouragement pour l'Industre National," a paper was read on the substitution of aluminium for wood in the machinery of spinning mills. In the textile industries—spinning, dyeing, and silk weaving, among others—a wooden bobbin is generally used. This is cheap and easily worked, but it has many drawbacks. Being very hygrometric, it suffers from variations of temperature; this accounts for the fact that in spinning factories where the atmosphere is full of humidity the bobbins revolve irregularly, causing jerks which slacken the speed and occasion the threads to break. The result is waste of stuff and loss of time in joining the threads again. It has been proposed to substitute aluminium for wood. Bobbins made of this metal revolve in any temperature and any degree of humidity; their relative lightness (five aluminium bobbins weigh no more than two wooden ones) allows the machines carrying them to move more quickly, or an equal speed may be obtained at less expense of power; finally, the smaller volume of the bobbins diminishes the cost of transport. It was stated that several firms had adopted the use of aluminum bobbins and had found that they possessed many advantages.

NEW METHOD OF COLOR PHOTOGRAPHY.—Auguste and Louis Lumière describe a new method of photographing in natural colors in *Comptes Rendus*, May 30, an abstract being given in the *London Electrician* of June 17. The method is somewhat similar to Joly's method, except that colored starch grains are substituted for tinted gelatine lines. From the starch of potatoes, the grains having a diameter of 15 to 20 microns are separated out. They are divided into three lots, which are colored orange-red, green and violet, respectively. After thorough drying, the colored powders thus obtained are evenly spread on a glass plate covered with a layer of isinglass. With care, one succeeds in spreading a very uniform layer only 1 grain in thickness. Then any interstices are closed up by means of a black powder, such as powdered wood charcoal. One thus obtains a color in which every square millimeter contains 2,000 or 3,000 elementary screens of the primary colors. The surface is then covered with a layer of thin transparent varnish having an index of refraction equal to that of the grains of starch, and, lastly, an isochromatic film of gelatine-bromide of silver is applied. The sensitive plate thus obtained is exposed in a camera in the ordinary way, except that exposure is made through the glass slide. A pure red surface produces a blackening of the film behind every red particle, leaving it unaffected behind the others. On developing and fixing, such a plate will, therefore, show the complimentary color of the original. To obtain the correct color, the authors dissolve away the reduced silver and develop the unexposed chloride. They thus obtain a transparency in the natural color without much more trouble than that of taking an ordinary photograph.

ELECTROLYTIC PRODUCTION OF HYDROGEN AND OXYGEN.

We have repeatedly described in our columns commercial apparatus for the production of oxygen and hydrogen gases by electrolysis of water; a comprehensive summary of methods for preparing and compressing these gases for experimental work was given in the paper by R. S. Hutton and A. E. Petavel in our April issue, 1904, page 139.

Hydrogen is at present mainly used for inflating military balloons, for autogenous welding and lead burning. For the



ELECTROLYZER FOR MAKING OXYGEN AND HYDROGEN.

latter purpose the oxy-hydrogen flame is also extensively used especially in connection with installing storage batteries, by various European storage battery manufacturers. As far as we know, the electrolytic production of hydrogen and oxygen for such purposes, has not yet found application in this country.

A new apparatus for making hydrogen and oxygen by electrolysis has recently been placed on the market by the Oerlikon Company in Zurich, Switzerland. The apparatus is made in various sizes, consuming up to 30 hp. while the voltage used may be up to 250. The apparatus contains a series of successive cells, the electrodes being brass plates. In its general con-

struction the apparatus is very similar to a filter-press. This will be seen from the adjoining illustration.

The different plates are insulated from each other by means of diaphragms which at the same time assure perfect tightness of the cells. The gases formed at the surface of the electrodes escape through holes in the plates. These holes communicate with two longitudinal canals which conduct the gases to separators in which the gas is separated from the liquid, the latter being conducted back to the cells through a single conduit. A continuous circulation of the liquid is produced by the development of gases due to the passage of the current.

The electrolyte consists of a 10 per cent solution of potassium carbonate. The design of the apparatus permits to obtain the gases under constant pressure, the value of which may be equivalent to the pressure of a water column of 2½ meters height. On account of the simplicity of construction, it is possible to clean the apparatus rapidly. If it is in continuous operation, it becomes necessary to clean it at intervals of about eight weeks. It is, of course, always necessary to add distilled water to the solution, to make up for the water decomposed by the current.

This apparatus decomposes 134 grams of water per kw-hour, and produces 168 liters of hydrogen and 84 liters of oxygen. At elevated temperatures, the efficiency is increased by 8 per cent.

The purity of the electrolytic oxygen is in the average 97 per cent, the 3 per cent impurities being hydrogen and some carbon monoxide. The electrolytic hydrogen on the other hand contains only one per cent of oxygen. By means of special and very simple devices, it is claimed, that it is possible to obtain the gases in a condition of perfect purity.

In the cold the electrolyzer requires 2.7 volts per cell, which is reduced at elevated temperatures to 2.3 volts. When the apparatus is started, the temperature increases for about eight hours; after this interval the temperature becomes stationary, being about 60° C.

On the basis of a price of 1.2 cents per kw-hour of electrical energy, the cubic meter of oxygen costs 14.1 cents, and the cubic meter of hydrogen 7.2 cents.

ST. LOUIS EXPOSITION.

International Acheson Graphite Company.

The exhibits of the International Acheson Graphite Co., are placed near the main entrance of the Electricity Building. They comprise miniature electric furnaces, illustrating the processes

EXHIBIT OF INTERNATIONAL ACHESON GRAPHITE CO.

of E. G. Acheson for manufacturing artificial graphite from anthracite coal, as worked on a large scale at the plant of the company in Niagara Falls (see description Electrochemical Industry, October, 1902, page 52). The exhibits comprise the different grades of graphite and various forms and sizes of electrodes, showing the great ease of machining Acheson graphite so that the graphite articles may be assembled in any desired form. For electric furnace work, when an electrode has been consumed, it is only necessary to join a new one to the end of the old one, and feed into the furnace one after the other without interrupting the operation. Other exhibits illustrate the use of Acheson graphite for the manufacture of paint, dry batteries, stove polish, motor generator brushes, etc. Special attention is given to the use of this form of pigment for high-grade protective coatings on structural iron and steel, for instance for bridges.

Hall's Plating Works.

An attractive operating exhibit is the Hall model electroplating establishment in the West doorway of the Electricity Building. The various steps in the processes of gold and silver plating are shown, such as cleaning the metal surface, depositing the electrolytic coating, cleaning and polishing. Electroplated leaves, fruit and flowers are specially attractive.

HALL'S ELECTROPLATING EXHIBIT.

Headquarters of Electrochemical Industry.

The headquarters of Electrochemical Industry will be in conjunction with the offices and exhibits of the McGraw Publishing Co. The space is at the head of the main aisle (section one) in the Electricity Building. The booth is elegantly and comfortably furnished for the reception of visitors. A library is provided with a very complete collection of engineering books, including important works on electrical, mechanical, mining, metallurgical and chemical subjects. Com-

BOOTH OF McGRAW PUBLISHING COMPANY.

plete files of the following publications are available for inspection and reference: Electrical World and Engineer, Street Railway Journal, Engineering Record, American Electrician, ELECTROCHEMICAL INDUSTRY, American Street Railway Investments, Electrical Railway List and Buyers' Manual, Central Station List and Manual of Electric Lighting. Facilities are provided for receiving mail in care of the McGraw Publishing Company, and a register is kept in which it is intended to have a complete record of all those interested in any branch of electrical engineering who go to the Exposition.

INTERNATIONAL ELECTRICAL CONGRESS.

For the International Electrical Congress, to be held in connection with the Exposition, the following foreign governments have appointed delegates: Switzerland, Prof. Ferdinand Weber, Prof. Francois Louis Schule; Norway and Sweden, Prof. S. Arrhenius; India, Mr. J. C. Shields; Mexico, Mr. Rafael R. Arizpe.

The appointments from Great Britain, France, Germany, Austria-Hungary, United States, Belgium, Italy, Denmark, Spain, Portugal, Australia, Japan, China, Brazil, Chili and Peru have not yet been made. It is stated that appointments are being made.

A DEOXIDIZER FOR THE USE OF STEEL MANUFACTURERS AND FOUNDERS.

One of the great difficulties which steel and iron manufacturers and founders, as well as copper founders, have to contend with, is the occurrence of blow holes, flaws and "pipes" in the ingots and castings. The cause of these flaws is well known; they are due to oxygen. In steel and iron making and casting the oxygen combines, unless it is prevented from doing so, with the carbon which is always present, to form carbonic acid, and this combining action takes place rather slowly and even during the solidification of the metal, so that blow-holes are always liable to be formed. In the case of copper the trouble is that cuprous oxide dissolves in fused copper.

The remedy is, of course, to apply some deoxidizing agent. In the case of copper, the practice is now to add a small amount of silicon-copper; the silicon takes away the oxygen from the cuprous oxide and forms silica (ELECTROCHEMICAL INDUSTRY, March, 1904, page 121). In the case of iron and steel castings, aluminium has been tried since it has a very great chemical affinity for oxygen, as shown by its extremely high oxidation heat. But a difficulty arises in this case on account of the lightness of aluminium which tends to flow on the surface of the molten metal; an interesting method of overcoming this difficulty, described in our November issue, 1903, page 533, is by the use of anti-piping thermit.

A method of very general applicability for removing the blow-holes and produce sound ingots and castings, is to add to the steel or iron an alloy of metals which will combine with all the occluded gases—an alloy, consisting of several metals, such as aluminium and manganese having a greater chemical affinity for oxygen than the metals to be cast, and one or more electronegative non-metallic elements or metalloids, such as silicon or boron. By taking up the oxygen from the castings, the elements of this alloy are converted into single, double or multiple silicates, borates, etc., which produce a readily fusable slag. This slag is very quickly formed and rises in the form of globules upwardly through the liquid and much heavier material of the casting and renders the latter pure and free from blow-holes.

On this general principle is based the preparation of an alloy which is made by Messrs. George G. Blackwell, Sons & Co., Ltd., of Liverpool, England, under the name of S. A. M. Alloy. It is added to the molten steel or iron in such proportions that practically only a trace of the constituents of the same or say less than one-tenth of one per cent. remain in the finished casting, it being, of course, understood that the iron added by the alloy is in such proportion that more or less of the same is not oxidized and remains in the finished casting, while the remaining elements of the alloy are practically completely oxidized and form a readily fusible slag. The actual quantity of the alloy added to the molten iron or steel will, of course, depend upon the amount of oxygen found to be contained in the iron or steel. It will, therefore, depend on the special conditions in each case, and experiments should be made in which the quantity of the S. A. M. Alloy added is varied from one-half per cent to 1½ per cent, until the best results are obtained. Under ordinary conditions from one-half to three-quarter per cent of the alloy will be found sufficient in the treatment of basic and other steel.

It is naturally of great importance that no impurities should be introduced into the bath by this alloy. This is fully taken into consideration in the preparation of the S. A. M. alloy. Outside the special elements, it contains about 1.10 per cent of carbon, 0.05 per cent of phosphorous and 0.01 per cent of sulphur. The method of using this alloy is very simple. In open hearth steel the rule is to add the alloy red-hot, broken up, to the stream of molten metal, as it is being tapped from the furnace into the ladle. It may also be added direct into the ladle. It should not be added through the slag, but to the clean metal. In making crucible steel, the rule is to break the alloy into small pieces, heat to red heat, mop off slag, and stir into the pot just before teeming.

While the alloy is of general applicability, it has been found to be especially useful in the manufacture of special high-class, products, like armor plates, gun-forgings, boiler tubes, etc. For marine boilers it is recommended to make the tubes from extra soft chrome nickel steel, practically free from manganese, and "kill" with S. A. M. alloy. Such a tube withstands the action of fire and steam to a remarkable extent. It is made by Messrs. George G. Blackwell, Sons & Co., Ltd., from their refined ferro-chrome, which contains, under one per cent of carbon or from their chrome-nickel alloy.

PERSONAL.

The Committee of Science and Arts of the Franklin Institute has decided to confer the Elliott-Cresson medal to Dr. HANS GOLDSCHMIDT in Essen-Ruhr, Germany, in recognition of his distinguished work in aluminothermics.

JUBILEE.—In view of the approaching fortieth anniversary of Dr. Charles F. Chandler's appointment as professor of chemistry at the foundation of the School of Mines of Columbia College, the alumni association of the University is raising funds to present his portrait to the university. Prof. Chandler is not only well known to all old students of Columbia, but is held in the highest esteem by chemists all over the world. He was the first American elected president of the Society of Chemical Industry. For the sake of electrochemistry he has done very enthusiastic and important pioneer work.

At the recent commencement exercises of Lafayette College, Mr. WILLIAM H. NICHOLS, president of the General Chemical Co., and of the Nichols Chemical Co., received the honorary degree of LL.D. Dr. Nichols has also been nominated by the council of the Society of Chemical Industry, to succeed Prof. Ramsay as president. For the second time in the history of this Society an American will be elected its president. The first to enjoy this honor was Dr. Charles F. Chandler, of Columbia University, as the representative of chemical science in America; the second one is Dr. W. H. Nichols, representing American chemical industries.

INDUSTRIAL NOTES

CAUSTIC SODA.—We have received from Mr. Max Mauran, superintendent of the Castner Electrolytic Alkali Co., Niagara Falls, N. Y., two sample bottles of their electrolytic

caustic soda. One contains pieces of caustic, broken out of a drum, showing the crystalline structure of the caustic very clearly. The samples in the other bottle are made up in form of moulded sticks. The company puts the caustic up in this form for laboratory use as it is a little more convenient in this way. Tests of the caustic soda concerning purity have shown that it is over 99.5 per cent NaOH.

Thermit.—We have received from the Goldschmidt Thermit Co. a small bottle containing a portion of the first thermit made in the United States from United States materials. The factory of this company has recently been installed in New York by Dr. O. Weil, chief chemist of the thermit department of Messrs. Th. Goldschmidt & Co. in Essen.

Rutile.—We have received from the American Rutile Company, Washington, D. C., samples of their rutile ores from their Virginia mines, and also a sample of their powdered rutile. While rutile has various applications, there is now a steadily growing demand for it on account of the increasing importance of ferrotitanium in the iron and steel industries. Concerning the effects of ferro-titanium we may refer to an article, vol. I., page 525, of this journal.

The "Metallurgical Company of America" has recently been incorporated under the laws of the State of New Jersey, with a capital of one million dollars, for the purpose of doing a general metallurgical business. The officers of the company are Walter Merton, president; Dr. F. Meyer, treasurer; L. Seeger, secretary. The directors of the company are B. Hochschild, J. Langeloth, Louis J. Magee, Walter Merton, F. Meyer.

Among the sales made by Crocker-Wheeler Company during the past week is that of electrical machinery to the value of about $30,000 to the Barbour Flax Spinning Co., Paterson, N. J. The equipment includes a 600-kw. standard direct-current, 250-volt generator, and motors, with ratings from 5 to 100 hp., aggregating 515 hp. Also for their plant in Baltimore, the W. & J. Knox Net & Twine Co., they have bought a 100-kw. generator and 75 hp. in motors. The United States Naval Academy, Annapolis, has just purchased two 250-kw. Crocker-Wheeler generators for a two-unit, three-wire lighting system; and the J. B. Williams Company, of Glastonbury, Conn., a 150-kw. engine type generator. Armour & Co., Chicago, who already use C.-W. motors to the amount of about 7,000 hp., have placed an order for three more machines aggregating 110 hp. Twenty-eight motors, of the same make, with a combined power of 253 hp., have just been purchased by the Traitel Marble Co., Ravenswood, L. I.

Since the equipment of factories with electric motors for individual and group drive of machine tools has become an extensive department of the business of the Crocker-Wheeler Company, this company is now going a step further. It has retained the well-known firm of Dodge & Day, of Philadelphia, Pa., and places the services of this firm at the disposal of its customers. The advice and recommendations about which customers of the Crocker-Wheeler Co. may consult this firm need not be confined to electrical details, but may include all problems of shop equipment and management.

Massena Water Power.—The establishment of the power plant of the St. Lawrence Power Co., at Massena, New York, seems to have had a great effect on the growth of that town, which but a short time ago was simply a summer resort. It is stated that in the last year and a half the population of Massena has been doubled, it now being about 7,000, and that in spite of the active building operations there are no houses available for renting. The St. Lawrence Power Co. is now supplying power to the Pittsburg Reduction Co., The Indestructible Fibre Co., The Massena Mineral Fibre Co., The Massena Pulp and Paper Co., The Massena Sash and Door Co., and The Massena Machine Works, as well as for lighting the town. The present development amounts to 35,000 hp.

DIGEST OF U. S. PATENTS

Prior to July, 1902.

Compiled by Byrnes & Townsend, Patent Lawyers,

National Union Building, Washington, D. C.

The Production of Sodium from Molten Electrolytes.

296,357. April 8, 1884, Augustus J. Rogers, Milwaukee, Wis.

Electrolyzes molten chlorides, bromides, iodides, fluorides, sulphides, oxides, etc., of potassium, sodium, calcium, barium, strontium, magnesium, aluminium, boron, silicon, phosphorus, etc. May use a mixture of compounds to increase the conductivity or fusibility of the electrolyte, *e. g.*, adds calcium chloride to potassium or sodium chloride, in equi-molecular amount, thereby lowering the fusing point from 730° to 500°. Similarly, adds potasium and ammonium chlorides to magnesium chloride. The apparatus comprises a rectangular cell of clay set in masonry, with an ordinary fireclay diaphragm which extends nearly to the bottom. The electrodes are carbon plates, having terminals which extend through the sides or top of the cell, and are protected from the electrolyte by clay tubes. The cell has a tight cover which seats on the diaphragm and has feed-openings and two goose-necks, one leading to a coil condenser for the electrolyzed sodium, and the other to a lime chamber. The cover also has an exhaust pipe for removing the air from the cell before starting. An atmosphere of hydrogen is maintained in the upper part of the cathode compartment to prevent oxidation of the sodium. The molten salt is supplied to the cell from a separate clay or iron melting pot, which has a valved outlet leading into the bottom of the cell beneath the diaphragm. The melting pot has a float-feed salt reservoir and a safety valve. The sodium condenser has outlets into two receptacles containing coal-oil.

452,030. May 12, 1891, Hamilton Y. Castner, London, England.

Electrolyzes molten caustic soda or potash, or a mixture of both, at the lowest practicable temperature, say 20° C. above their melting point, to prevent recombination of the ions and volatilization of the metal. The cell is a circular iron vessel having a central extension from its bottom through which passes the cylindrical carbon cathode. The joint between the bottom cell extension and the cathode is filled with a solidified sleeve of caustic, the extension being exposed to the air to keep it cool. The cathode extends up into the cell and is surrounded by a tubular anode of a metal which will resist oxidation. A tubular iron receptacle opens into the electrolyte directly above the cathode, and has an iron wire gauze cylinder, which extends down between the cathode and anode. The electrolyzed metal rises into the receptacle and is removed by a perforated spoon or skimmer. A cell for holding 250 pounds of electrolyte employees a cathode four inches in diameter. The electrolyte may be maintained in a molten condition by the current. The preferred temperature for caustic is specified as 310° C.

464,096. December 1, 1891, Ludwig Grabau, Hanover, Germany.

Electrolyzes molten alkali chlorides in a vessel having a cover through which pass the carbon road anodes, arranged in a circle. The vessel has a lateral chlorine outlet at the top. A bell of porcelain, with a double wall which opens at the top, depends into the electrolyte. An iron tube containing a boring tool passes down through the top of this bell and serves as the cathode, having a wire extension with a cross-piece at its lower end. A lateral outlet for the sodium leads from the iron tube into a condensing vessel which is filled with hydrogen or nitrogen and dips into petroleum.

(*To be continued.*)

Electrochemical Industry

VOL. II. NEW YORK, AUGUST 1, 1904. No. 8.

Electrochemical Industry

Published on the first of each month by the
ELECTROCHEMICAL PUBLISHING COMPANY,

[*Incorporated.*]
114-118 LIBERTY STREET, NEW YORK.

J. W. RICHARDS, PH. D. .....*President.*
E. F. ROEBER, PH. D. .....*Editor.*

Telephone Call: 7607 Cortlandt.

Subscription Price: $2 per year, postpaid to any part of the world. Single copies 25 cents.

ADVERTISING RATES GIVEN ON APPLICATION.

Copyrighted, 1904, by the Electrochemical Publishing Co.

Entered as Second-Class Matter, June, 1903, at the Post-Office at New York, N. Y., under the Act of Congress, March 3, 1879.

CONTENTS.

Editorial 297
International Congresses and Society Meetings..... 300
Power Transmission for Electrochemical Works. By Louis Bell.. 301
Reduction of Metals. By Oscar Nagel..... 302
The Pioneer Electrolytic Copper Refinery of the United States..... 303
The Rapid Measurement of the Conductivity of Copper Electrolytes. By Lawrence Addicks 306
Application of the Electric Furnace to the Metallurgy of Iron and Steel. By P. McN. Bennie..... 307
A Contribution to the Theory of the Jungner-Edison Accumulator with Constant Electrolyte. By M. U. Schoop..... 310
An Index to Electrochemistry and Its Applications. By A. Voege. 313
German Bunsen Society. By H. Danneel..... 315
Solubility of Gold in Certain Oxidizing Agents. By V. Lenher.... 316
The Edison-Jungner Case..... 317
Synopsis of Articles in Other Journals..... 318
Analysis of Current Electrochemical Patents. By G. P. Scholl..... 323
Recent Metallurgical Patents 328
Current Notes 328
Correspondence: Electrometallurgy of Iron and Steel. By E. Haanel 329
Book Reviews: Hering, Ready Reference Tables..... 329
Transactions American Electrochemical Society..... 330
Moissan-Lenher, Electric Furnace..... 330
Treadwell, Quantitative Analysis 331
St. Louis Exposition 331
Gas Blowers and Exhausters 332
Electrically Operated Steam Whistle..... 332
Personal 333
Industrial Notes 333
Digest of United States Patents, Prior to July, 1902. By Byrnes & Townsend 333

INTERNATIONAL CONGRESSES AND SOCIETY MEETINGS.

In connection with the St. Louis World's Fair a greater number of international congresses will be held during September and October; of those which should be of special interest to our readers, the Electrical Congress promises to be of the greatest importance and it seems fortunate that the American Electrochemical Society has cast its lot with the Electrical Congress. Much good can come from a more intimate intercourse between electrochemists—who are, after all, primarily chemists and metallurgists—and the workers in other fields of electrical engineering. An excellent and elaborate programme has been arranged for the first American meeting of the Society of Chemical Industry, to be held in September in New York City, and for the following trip of members and guests through the country, taking in the two chemical congresses in St. Louis. Two of our national engineering societies have also arranged attractive trips through the country, viz., the American Institute of Electrical Engineers and the American Institute of Mining Engineers. Condensed programmes of the various meetings and excursions are printed on another page of this issue, while we will print detailed programmes in our next issue.

THE LEAD ACCUMULATOR AND THE OXYGEN-LIFT CELL.

This issue contains the conclusion of the able paper of Mr. M. U. Schoop on the theory of the oxygen-lift cell. The simple and ingenious method of studying the variations of weight of an electrode, suspended on a balance, during and after the passage of a current, at various discharge rates, enables the author to investigate the concentration changes developing in the pores of the plates during discharge, together with the resulting diffusion phenomena, and to determine the changes of the specific weight of the active materials, due to contraction or expansion. Mr. Schoop's paper contains the first published results of experiments enabling us to follow up more in detail the reactions in the Edison battery. His results are especially interesting in the light of our knowledge of the corresponding reactions in the lead accumulator. It is quite interesting to compare the behavior of the lead accumulator with that of the Edison battery and to explain the difference of their behavior by the difference of the chemical reactions.

During discharge of a lead cell, sulphuric acid is consumed at both plates, since both the lead peroxide and the spongy lead change to sulphate; an amount of acid is therefore removed from the electrolyte, proportional to the ampere-hours given out by the cell. During discharge of the Edison battery, the active nickel material is reduced from a higher state of oxidation to a lower one, while the active iron material is oxidized to a higher state of oxidation; the total amount of

KOH in the electrolyte remains constant. Since the equation of the reaction in the lead accumulator shows the participation of the electrolyte in the reaction producing the current, the principles of thermodynamics require that the electromotive force should depend on the concentration of the acid. On the other hand, since the equation of the reaction of the Edison battery does not contain the electrolyte at all, its electromotive force must be independent of the concentration of the KOH solution. Both these conclusions from the principles of thermodynamics have been confirmed experimentally. During discharge the concentration of the acid in the lead accumulator decreases, hence there must be a corresponding drop of the electromotive force. For the Edison battery we cannot make a parallel statement.

The place where any electrolytic reaction occurs is in the molecular layer at those places of anode and cathode where oxidation or reduction occur respectively. The active material of every storage battery has a certain measurable thickness, and during discharge the places of oxidation and reduction are moved from the outside layer of the plate to the inside. When the discharge has gone on for a certain time, the points of the electrodes at which the electrolytic reaction occurs is no longer in contact with the main quantity of electrolyte between anode and cathode, but with the electrolyte in the pores of the plate; and the electrolyte in the pores of the plate will differ from the outside main portion of the electrolyte and this difference will be the greater, the higher has been the discharge rate, since for a high discharge rate diffusion and convection currents have not sufficient time to destroy developing concentration changes. This fact has the following consequences for the lead accumulator and for the Edison battery. During discharge of the lead cell the concentration of the acid in the pores of both plates decreases more rapidly than that of the main portion of the electrolyte. During discharge of the Edison battery the concentration of the potassium hydroxide solution increases in the pores of one plate and decreases in the pores of the other plate, while the concentration of the main portion of electrolyte remains constant.

These facts are of consequence for the drop of the electromotive force. The electromotive force of a lead accumulator, when discharged at a high rate, will drop more rapidly than corresponds to the decrease of the concentration of the main portion of electrolyte between the plates; in other words, the higher the discharge rate, the greater the voltage drop. On the other hand, it is possible to show thermodynamically that the change of the electromotive force of the Edison battery, due to the local concentration changes, is of less practical importance; this is the reason why the Edison battery stands high discharge rates much better than the lead cell. Nevertheless, Mr. Schoop's experiments show that there is a measurable variation of electromotive force, due to local concentration changes in the pores of the plates. It is especially interesting to observe what happens when the current is interrupted after a discharge with a high rate. In the lead accumulator fresh acid passes into the pores and the electromotive force rises correspondingly. The same phenomenon is evident in Mr. Schoop's tests of the iron electrode of the Edison battery. On the other hand, this phenomenon is masked in the nickel electrode by other phenomena of far greater importance. Concerning the change of internal resistance we have already spoken in our last issue; here again the situation is quite different in the Edison battery from that in the lead cell.

While Mr. Schoop's experimental results fully confirm the conclusions of the theory concerning concentration changes in the Edison battery and their consequences, his results concerning expansion and contraction of the active masses represent something new which could not be predicted by the theory. All theoretical conclusions concerning concentration changes in the Edison battery are independent of the chemical nature of the active materials of the electrodes, *i. e.*, the same concentration changes should take place with a KOH solution, whether we have a nickel-iron or a silver-cadmium cell, as long as it really is an oxygen-lift cell. Moreover, it should not matter whether the reaction at the nickel electrode is, for instance, the reduction from NiO_2 to Ni_2O_3, or from Ni_2O_3 to NiO or something else; a certain number of ampere-hours should always give a certain change of concentration. But the knowledge of the exact nature of the chemical reaction at the active materials becomes important in connection with their expansion and contraction. Here is a very promising field for experimental research, and when experiments supply us with the necessary data, we may hope to see the principles of modern physical chemistry applied to the explanation of all details of the behavior of the Edison battery with the same success as they have been applied in the case of the lead accumulator.

A UNIVERSAL LANGUAGE.

Prof. Wilhelm Ostwald is a man of most versatile genius. Everybody knows his important and inspiring pioneer work in electrochemistry and physical chemistry, his work as an original investigator, teacher and author. Then he has been interested in what he calls energetics and has endeavored to build up a new system of antimaterialistic metaphysics—essentially a glorification and idolization of energy. Recently he surprised his friends by his Letters of a Painter; and still more recently he delivered a lecture before a local section of the Association of German Engineers on the necessity of a universal international language, and this lecture was afterwards distributed in print at the annual meeting of the Bunsen Society. Prof. Ostwald requested the co-operation of the members of the Society in his endeavor to bring this scheme nearer to realization. The scheme may seem fantastical, but is fascinating, and it should be considered not in its relation to philology—in this respect we could not speak about it—but in its relation to international commerce for which it is possibly of similar importance as telegraphy, telephony and railroading. Manufacturers and merchants would probably gain most by its realization, but it is also of importance for scientists, since the scheme of a universal language is in intimate connection with that of uniform notation of scientific terms.

The idea of Prof. Ostwald is that everybody should learn two languages, the language of his nation and the universal language. He has been asked why we should not make English the universal language, and thinks this would not do for two reasons: Other nations might not be unselfish ("selbst-

los") enough to recognize English as the standard language and, then, English is not simple enough. An artificial language could be rendered much more simple. Prof. Ostwald refers to an occurrence at an international scientific congress. There were four professors who would have liked to talk with each other; one came from Germany, the others from Norway, Roumania and Belgium; all could read several modern languages, but could not speak them, but the latter three spoke "esperanto," an artificial language. They came along all right, while the German was out of the race. When he inquired of the others how long it had taken to learn "esperanto," he was told two or three weeks. Prof. Ostwald mentions this to prove that the scheme is feasible; it makes no difference to him whether the universal language shall be volapük or esperanto or something else; he leaves it to the philologists to work the language out and he leaves it to an international congress in which the different nations are represented by official delegates, to decide on the language. The idea may be phantastic and may never be realized, but it is certainly not ridiculous. It is capable of realization, and if our manufacturers shall continue to extend their export trade, they will surely prefer to deal with their foreign customers in a simple artificial language than in the various languages of the countries to which they export their goods.

The comprehensive scheme of Prof. Ostwald intends to give to all the people an international language such as, in the realm of their own science, chemists already have in chemical notation. N means the same element all over the world, whether we speak of nitrogen or the Germans of stickstoff, or the French of azote. A chemical equation confers the same information to everybody, although if expressed in words, it sounds quite different in different languages. The difficulties, however, which are likely to arise in the comprehensive scheme of an international language for everyday life, are already indicated in our special case by the tenacity with which some chemical scientists insist on H = 1, against O = 16. Nevertheless, chemical notation on the basis of molecular theory is a nearly perfect example of the advantages which we would get by a universal language. It is regretable that there is much less uniformity in the notation of physical chemistry and electrochemistry. Thus, the list, proposed by the Bunsen Society at the last International Congress for Applied Chemistry and published in our issue of last November, contains some Germanisms, like W for resistance, which will never find universal approval. With his abundance of energy—or we should rather say thermodynamically "free energy"—Prof. Ostwald could do more than anybody else to bring about uniformity of notation in these special fields.

We may use this opportunity to say a few words concerning our systems of units and measures. They represent those quantities which are most important to engineers in all their work, and the trouble is that the different nations have not only different names for the same physical quantity, but that the quantitative values of the unit itself are different. Lord Kelvin said once: "I look upon our English system as a wickedly brain-destroying piece of bondage under which we suffer." These words are as true as when they were spoken in Philadelphia twenty years ago, though much has been done in the meanwhile towards uniformity, so that we may even hope to see the day when the metric system will be in universal use. A good part of the general progress has been due to the rapid development of electrical engineering. With units based on the centimeter-gram-second system electrical engineers were naturally not handicapped from the start with the burden of arbitrary relations, reigning supreme in other departments of engineering.

In the matter of units the development of electrical engineering has thus exerted a beneficial influence on engineering in general. Nevertheless, we notice even here some curious facts in special instances. Thus, as the unit of electric resistance we have universally the ohm. But here the same name covers various quantities. We have the "international" ohm, as defined in Chicago in 1893 as the resistance of a column of mercury of uniform cross-section, at 0° C., 106.3 cm. long and weighing 14.4521 grams. We have had the "legal" ohm for which the length of mercury is 106 cm., the other figures being the same. We have the "true" ohm, being 10^9 electromagnetic c. g. s. units. Thus the value of the ohm is only a matter of definition, and in engineering practice it does not cut any figure which ohm we mean. Practical engineers would not stand for any uncertainty that would matter in practice. The subject of units will come up again for consideration at the International Electrical Congress in St. Louis, but the national society of electrical engineers in Germany has already announced that it does not like to render its aid to the proposed changes of units, and will therefore not send delegates to the congress. We have mentioned this instance to show the difficulties in the way of international agreements in cases where the necessity of absolute uniformity is not denied by anybody. In the light of this tiresome experience, Prof. Ostwald's scheme of reaching an international agreement on the subject of a universal language might seem absolutely hopeless. Yet the latter subject should appeal to manufacturers and business men. A successful business man knows a good thing when he see it, and he knows how to accomplish something if he wants it. Any progress that should be made in the direction of a universal language would be a splendid subject lesson to scientists.

SOLUBILITY OF GOLD.

In the operation of the cyanide process it has long been recognized that for the solution of gold in potassium cyanide solutions a supply of atmospheric oxygen is very important. In those electrolytic processes in which the electric current is used for dissolving the gold, it is probable that the action of the current is essentially to supply the oxygen required for solution. In this connection it is interesting to note the results obtained by Dr. V. Lenher, as published on another page of this issue. He shows that gold is not only attacked by halogens, but is also readily attacked in a large number of reactions in which oxygen is produced. Anodic oxygen, for instance, is very active. A plate of metallic gold, used as anode, dissolves in an electrolyte of sulphuric acid or a mixture of nitric and sulphuric acid. But it is not necessary that the oxygen is produced by the electric current; on the other hand, it appears that it is necessary for the oxygen to be produced in the mixture and that ordinary oxygen gas, where conducted into sulphuric acid in which gold leaf is suspended, will not cause the gold to dissolve.

INTERNATIONAL CONGRESSES AND SOCIETY MEETINGS.

In connection with the St. Louis World's Fair a number of International Congresses will be held.

The *International Electrical Congress* will convene in St. Louis on Monday, September 12, 9:30 a. m. The opening ceremonies will be held in the music hall of the Coliseum at Olive and Thirteenth Streets. The meetings of the eight sections follow, commencing at 11:00 o'clock a. m. in the section hall on the second floor of the Coliseum, the sections adjourning on Monday, at 1:30 p. m. On Tuesday, Thursday and Friday the sections will meet on the second floor of the Coliseum at 9:00 o'clock a. m., and will adjourn not later than 1:00 p. m. Programmes of the papers to be presented were published on pages 214 and 258 of our June and July issues.

The *Congress for Inorganic and Organic Chemistry* will be held on Wednesday, September 21, the *Congress for Technical, Physical and Physiological Chemistry* on Thursday, September 22.

The *International Engineering Congress*, arranged by the American Society of Civil Engineers, holds its sessions in St. Louis from October 3 to 8.

The *American Electrochemical Society* will hold its meeting at St. Louis on the 13th, 15th and 16th of September. On the 13th and 15th joint sessions will be held with section C (Electrochemistry) of the Electrical Congress and on the 16th a joint session will be held with the Bunsen and Faraday Societies. Sessions will be held only in the morning. No session is being arranged for the 14th, as it is thought by officers of section C that if an independent meeting is set for the 16th, rather than the 14th, the section may be through its work by that time and be able to attend the session of the Society.

The annual convention of the *American Institute of Electrical Engineers* will be opened on Wednesday, September 14, at 10:00 a. m. at Festival Hall and the president of the Institute, Mr. Bion J. Arnold, will deliver the annual address. Immediately afterwards a topical discussion will follow between the Institution of Electrical Engineers of Great Britain and the American Institute of Electrical Engineers, the subject of which will be announced later. Arrangements are being made for holding a closing meeting of the International Congress.

At the invitation of the American Institute of Electrical Engineers a large number of members of the (British) Institution of Electrical Engineers, being accompanied by their ladies, are expected to arrive in this country by the White Star Steamship "Republic," reaching Boston on the 22d. They will travel from Boston to New York. After that a special circular tour for foreign delegates, visiting electrical engineers and guests has been organized under the auspices of the American Institute of Electrical Engineers. This tour begins on September 6, and covers visits to Schenectady, Montreal, Niagara Falls, Chicago, St. Louis, where the party stays from September 11 to September 17; after this, Pittsburg, Washington, Philadelphia and New York.

The eighty-seventh meeting of the *American Institute of Mining Engineers* will be held in the Lake Superior iron and copper regions, beginning at Duluth, Minn., on Wednesday, September 14. An excursion has been arranged in connection with this meeting, starting on September 10th from Buffalo, with visits to Cleveland, Detroit, Mackinac Island, Sault Ste. Marie, Duluth, where the party stays from the 13th to the 18th, a trip to the Masebi range being sandwiched in for the 16th and 17th. Duluth is left on September 18 for Houghton, Ispheming, Mich., and Chicago, where the party arrives on the 22d. Those who desire to visit the St. Louis Exposition will then proceed to St. Louis, where a session will probably be held on Monday, September 26, for the presentation of papers, etc., aiding in the study of the mining and metallurgical features of the Exposition. Members may then take part in the International Engineering Congress from October 3 to 8.

The *Society of Chemical Industry* will hold its first American meeting in New York City from September 7th to 11th, for which a most elaborate programme has been arranged, a general outline of which was given in our April issue, page 148, which will be fully carried out, all arrangements having been completed. Over eighty (sixty-seven gentlemen and fourteen ladies) from abroad have already signified their intention of accepting the invitation of the New York Section of the Society of Chemical Industry, and this list is being added to from time to time, and it is hoped that the final number will be not less than 100. The expense of entertaining members from abroad while in New York, and for the cost of their transportation and sleeping accommodations on the round trip through the country is covered by subscription by the New York Section. On the round trip the following places will be visited: Philadelphia, Washington, Pittsburg, St. Louis, Chicago, Detroit, Buffalo, Niagara Falls, Boston and back to New York. For the visits of these places, a most elaborate programme has been arranged. The members participating in the trip will attend the congresses for Inorganic and Organic Chemistry, and for Technical, Physical and Physiological Chemistry in St. Louis on September 21 and 22.

More detailed programmes of the various meetings and congresses will be published in our next issue.

GERMAN CHEMICAL INDUSTRY.

The recent annual meeting of the Association of German Chemists, held at Mannheim, led to the publication of interesting statistical information as to chemical industries in Germany. In 1897 the total value of the more important manufactured products of Germany was about $2,120,000,000. At the top of the list stood the products of the iron and mining industry, with a value of nearly $840,000,000. Next came textile manufactures, whose value in round numbers was $650,000,000. This was followed by chemical manufactures with a total value of about $226,000,000. Including with chemical products proper those of the rubber, gutta-percha, celluloid, paper and wood pulp factories, the total output in 1897 was approximately $256,000,000. In 1903 the total production of the German chemical factories, using the term in its narrower sense, was estimated at $321,000,000. This industry has shown a marked tendency in Germany to concentrate in certain localities without special reference to the sources of raw material. The most important centers are the Barmen-Elberfeld region, Frankfort on the Main and its environs, and the Mannheim-Ludwigshafen district, which includes the two towns named, separated only by the Rhine. In the variety of its products and the magnitude of some of its undertakings, the last-named district leads all the others. In it are located at present seventy-three factories for the manufacture of chemicals. Of these, thirty-seven are to be reckoned as important, the remainder being small. Eleven of the thirty-seven are located at Ludwigshafen and twenty-six are at Mannheim. The seventy-three factories employ a total of 15,325 workmen; the total population in the two cities dependent upon this branch of manufacturing is not far from 55,000. As to character of products, the factories group themselves somewhat as follows. First, factories for the manufacture of inorganic products, acids, salts, fertilizers, etc. (thirteen factories). Second, factories for the manufacture of coal-tar products, oils, fats, varnishes, etc. (thirteen factories); among these is included the Badische Anilin and Soda Fabrik, the largest of its kind in the world, employing now 7,800 workmen, besides about 1,000 chemists and office employees. Third, rubber, celluloid and wood pulp factories. This group includes the largest wood pulp factory and the largest celluloid factory of Germany, the two factories employing somewhat more than 3,000 workmen. The value of the present yearly output of these two cities is estimated at $32,000,000.

POWER TRANSMISSION FOR ELECTROCHEMICAL WORKS.

By Louis Bell, Ph. D.

The rise of electrochemical industry has produced a new set of problems in the generation and transmission of power. The first necessity in electrochemical works is an abundant, and, above all things, cheap supply of electrical energy, for in no other class of manufacture is power so large a proportion of the expense account. A machine shop may pay a fairly high price for its power and still, through the incidental reduction of losses and improvement in output that follows the introduction of motors, be able actually to reduce the power charge against its product to a very modest figure. In electrolytic reduction works, on the other hand, the process itself demands electrical energy in amount which bears a predeterminable relation to the output, and the final economic result hinges mainly, if the reactions concerned are reasonably clean, on the cost of this energy.

The power supply must also be regulable to an extent which is unusual in other classes of manufacture. In some processes accurately uniform voltage is of the first importance, in others a voltage which may be held steady over a very wide range of values is necessary, and in still others commercial success depends upon absolute continuity of the power supply. Each process has its own special requirements, which must be met under penalty, not of delay or inconvenience, but of failure and serious loss. Hence, the demands of electrochemical works on the generating plant are necessarily severe, and comparatively few stations can meet them without special precautions.

Broadly, it is, therefore, best for electrochemical industries to own and operate their own generating plants. The next best thing is to locate near an ample source of power already developed. As a commercial proposition, current for electrochemical uses is often a somewhat undesirable load for a supply station, in view, first, of the sometimes severe requirements, and, second, of the fact that motors and lights at ordinary current prices constitute a more profitable load. There are, however, two cases in which good terms can be made between a supply company and electrochemical works. The first is where the electrical development, as at Niagara, is on so enormous a scale that the market prices are in a measure controlled by a relatively moderate, although absolutely very great demand, and the size of the plant renders it easy to take care of even the severest demands. Instances of this kind are obviously not common. The second case is where the electrochemical demand for power is not necessarily continuous throughout a long working day. The salable energy of a plant is limited by the conditions of maximum demand, and since in a hydraulic installation the operating cost varies but little with the output, energy which can be added to the output sold without increasing the peak of the load can well be sold at a moderate figure.

For example, a chemical plant that, by reason of its process, could undertake to demand no power between 3 or 4 p. m. and midnight, could make extremely good terms with a great many hydraulic plants, and would form a welcome addition to the load. If electrochemical works can be operated discontinuously at all they can be worked at odd hours more readily than any ordinary manufacturing establishments. This phase of the situation is well worth the attention of one who is contemplating the establishment of an electrochemical process.

There are not a few power plants which have sold their output up to the limit of their generating capacity at the peak of the load, and which would find it to their interest to sell their power available except at the peak, at a moderate figure, rather than to provide a supplementary steam plant or heavy storage battery to take care of an increased peak.

So much for the general economic conditions. As to the concrete question of cost of electrical energy it must be considered under two heads, supply from a separate corporation and supply from a plant of one's own. The market price of power varies prodigiously from place to place. Aside from Niagara, the ruling prices for cheap electrical energy for motors range from $15 per horse-power-year up, for ten to twelve hours per day—roughly, half a cent per electrical horse-power-hour—two thirds of a cent per kilowatt-hour. This figure is seldom bettered, in fact rarely reached, and can be made by very few plants unless at a loss. The number of hydraulic stations for general power supply able to make such quotations, save for power off the peak period is, and always will be, very limited. Anything under a cent per kilowatt-hour is very cheap power indeed, even to large consumers. As already intimated, the best chance to get these low figures in electrochemical work is to make terms for power at times of otherwise light load, when the character of the process permits. Under any ordinary circumstances, when energy can be had at or below one cent per kilowatt-hour, it is cheaper for the average large consumer to buy it than to produce it in a plant of his own.

In the case of large electrochemical works, however, it undoubtedly pays to make a very thorough examination of locations in which good transportation facilities are joined with the possibility of getting within reach of an available water-power for development. The engineer is very often asked as to the distance to which it is economically advisable to transmit electrical power. While the question cannot be answered off hand, experience has shown that up to twenty or twenty-five miles the total cost of transmission is not at all serious. Beyond this one should go into details rather cautiously, although, of course, there are many longer transmissions which have proved to be economical, although not with a market requiring very low prices.

Within moderate distances the critical point of economy is the cost of developing the hydraulic power. This varies enormously, according to local conditions. In any region where electrochemical work is likely to be carried on hydraulic rights have to be purchased at prices varying from, say, $5 to $25 per horse-power available throughout the year. Then comes the work of development, building dam and canal, blasting and dredging, building roads and retaining walls and power house and setting wheels. The total is most uncertain—almost anything from $25 or so per horse-power to $100 or more. The latter figure would be too large for serious consideration in connection with electrochemical work, and the smaller requires a rare combination of good fortune and low prices. As a rule, the hydraulic rights and development form together rather the larger half of the total cost of getting a power transmission under way. Of late years the costs of electrical machinery have fallen considerably, while the hydraulic construction costs have risen a little.

The line itself, owing to the present use of high voltages, has ceased to be a formidable factor in most transmissions. Ten thousand volts is about the lowest electrical pressure in vogue, and two or three times that voltage is common. At the usual line loss of 5 to 10 per cent the cost of the conducting wires can generally be kept down to, say, $5, and the total line cost to below $10 per kilowatt. Generators, and raising and reducing transformers are subject to considerable variation of cost with the speed and size of the first-named and the voltage and size of the others. Large output and high speed are conditions favorable to low cost. At the present time very excellent generators are made to deliver directly 10,000 to 12,000 volts and for transmission plant of moderate capacity at the shorter distance, say, up to a dozen miles, it is often cheaper to use these than a combination of low voltage generator and raising transformer. Roughly, the generator and transformer costs all together commonly run from $15 to $25 per kilowatt capacity of plant, reaching the lower limit only in large work under very favorable conditions.

Lumping all these various items of cost one may say in general that an electric power transmission plant from water

power, over a moderate distance, such as has been presupposed, is likely to cost from $60 to $100 per kilowatt capacity delivered on the low-tension side of the reducing transformers. Against this must be charged suitable interest depreciation and taxes, together with some general expense and the operating charges. A good deal of fog surrounds the matter of the fixed charges. Published costs of power generally are based on general and operating expenses only, but there is no good to be gained by deceiving one's self as to the final costs.

Private plants, such as are here being considered, probably fare better in the matter of depreciation and maintenance than most plants for general distribution of power. In the first place they have a relatively small amount of circuits to maintain, and they also suffer less acutely from depreciation due to change in the art, a serious item in public supply stations. The latter may be from time to time forced by competition or the current requirements of public service to make extensive changes in equipment at large cost. A private plant is installed to furnish electrical energy for a certain well-defined purpose, and as a rule the character of the demand will remain uniform, however the amount may increase.

No change can in the nature of things materially increase the efficiencies of generators, transformers and line, so that the depreciation to be dealt with is almost entirely physical, and modern apparatus enables one to make a good showing in this respect. Not to go too far into details, the average hydraulic electrical transmission plant is likely to find its total expense about equally divided between fixed and general charges, on the one hand, and operating expenses on the other.

As a matter of experience, this total is likely to amount to between 15 and 20 per cent of the total cost of the plant. Anything less than the former figure is a remarkably favorable performance. It is more likely to be reached in a large simple transmission, such as electrochemical works require, than in a more general distribution, particularly when the demand for power is such as to utilize the plant steadily for a large proportion of its capacity.

With this as a basis one may fairly reckon that the cost of power delivered in plants of the kind considered will be likely to be between $10 and $20 per kilowatt-year for twenty-four-hour power.

The former figure would be very exceptionally low, the latter rather high. Now, from this reckoning it plainly appears that the prices commonly charged by public supply companies working from cheap water power, are, upon the whole, very moderate, considering the risks assumed, and the difficulty of selling anywhere nearly up to the full capacity of the plant.

Fixed charges and attendance go right along day by day, irrespective of load, and a plant half utilized becomes a serious burden at times.

The special electrical apparatus required by electrochemical works to deliver particular kinds of output, such as low-voltage transformers, regulating apparatus with a wide range, and motor generators or rotary converters for delivering direct current, have been excluded from this discussion, as they really form part of the mechanism of utilization rather than transmission, and must be provided whether the electrical energy is purchased as such, or generated. Each industry has its own difficulties in this particular, and no general conclusions can be safely drawn.

The main thing is to come to a broad understanding of the cost of the energy which is the staple material of all electrochemical processes, and of the nature of the items which make up that cost. Small electrochemical works, demanding a maximum output of only a few hundred kilowatts can commonly make better terms with an established source of supply than they can make on their own account, unless an extremely favorable location near water power can be secured. Plants demanding considerably larger amounts of power can often generate it to advantage. In either case it is a case for careful engineering and a very close study of local conditions, which in the last resort determine the economy of power production.

REDUCTION OF METALS.

By Oscar Nagel, Ph. D.

At the last meeting of the American Electrochemical Society some statements were made regarding the reduction of metals, especially of zinc, that were not quite correct (Electrochemical Industry, May, p. 185 to 187).

The assumption of carbon vapor in the reduction process is a hypothesis that shows no advantage and lacks every foundation. The mentioning of reduction by means of carbon monoxide is also not very accurate.

The reduction of metals is based in general on the following equations (G. Bodlaender, *Zeitschrift f. Electrochemie*, VIII., 44). .

I.—$C + 2O = CO_2 + 97{,}650$ cal.
II.—$CO + O = CO_2 + 68{,}000$ cal.
III.—$C + O = CO + 29{,}650$ cal.

Since the heat of formation or heat of reduction in I. is larger than in II. and that in II. again larger than in III., it would seem as though for substances which are reducible only with great difficulty, equation I., and for easy reducible substances equation III. would be the correct expression. But just the opposite is the case. III. is the correct expression for substances reducible with great difficulty, like zinc, sodium, calcium-carbide, carborundum, phosphorus, manganese, and silica, II. for relatively easily reducible materials like iron, and I. for very easily reducible substances, like silver, copper and lead.

It is, therefore, apparent that the sequence of the free energies of reduction is just contrary to the sequuence of the heats of reduction.

It is well known that in the reduction of zinc the quantity of free energy has to decrease. At absolute zero the energy of formation of zinc oxide is about three times as large as the energy of carbon monoxide.

Therefore—as the reduction is really taking place at a certain temperature—the proportion of these energies is undergoing a change with the changing temperature. At 1125° C. the energy of formation of zinc oxide is equal to the energy of carbon monoxide. This is the reducing temperature of zinc.

The reduction of zinc oxide by means of carbon monoxide at 1000° C. stops with a content of 0.1 per cent carbon dioxide in the gases and at 1500° C. with a content of 0.76 per cent carbon dioxide.

The reduction of zinc oxide, exclusively by means of carbon monoxide, would therefore require a temperature not in reach of our present methods.

Conclusions:

(I.) Formula II. does not play any part in the present method of zinc reduction.

(II.) The assumption of carbon vapor is an unnecessary hypothesis.

Union Engineering Building.—The committee of the three national engineering societies and of the Engineers' Club has made the selection of architects for the new buildings. The successful competitor for the Union Engineering Building is Mr. Herbert D. Hale, of Boston, with Mr. Henry G. Morse, of New York, as associate architect. The successful competitors for the Engineers' Club are Whitfield & King, of New York. The United Engineering Building will occupy 125 ft. front by 100 ft. on West Thirty-ninth Street, while the Engineers' Club, with a frontage of 50 ft. and a depth of 100 ft., will face on Bryant Park and the new Public Library. The club building will be 11½ stories high, with the usual accommodations of a club and some sixty or seventy bedrooms for members.

THE PIONEER ELECTROLYTIC COPPER REFINERY OF THE UNITED STATES.

Copper refining is that field of metallurgy in which electrochemical methods have attained the greatest industrial importance, and it is in the United States that electrolytic copper refining has undergone the most important development. This is indicated by the fact that more than 85 per cent of the copper electrolytically refined in the world, is refined in the United States. There are only ten electrolytic refineries in this country, but all of them have a large output, and the total output of these ten refineries is about 280,000 tons per year. Under these circumstances it is, perhaps, surprising that the oldest American refinery is not older than about twenty-four years, somewhat younger than the electric incandescent lamp. This is not incidental. The development of electric lighting created a demand for pure copper, while the development of dynamo-electric machinery going on in connection with the erection of central stations, turned attention to electrical means for refining copper.

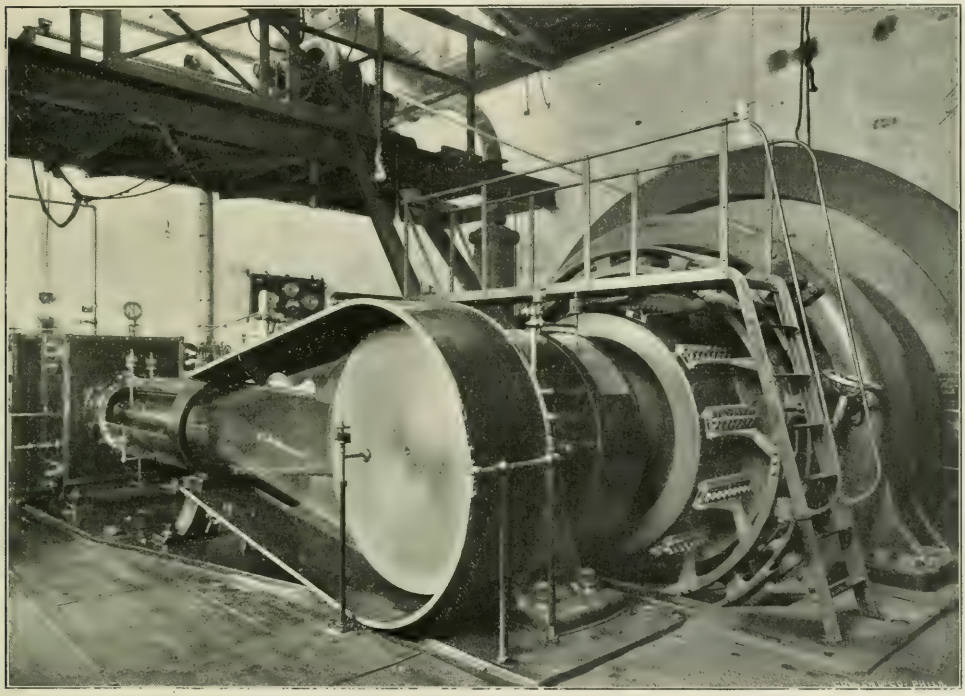


FIG. 1.—POWER PLANT OF THE BALBACH SMELTING AND REFINING COMPANY.

As a laboratory experiment, electrolytic copper refining is perhaps the simplest electrolytic reaction which can be imagined. On the other hand, this example shows very clearly the enormous difference between an experiment carried out on a test-tube scale, and the industrial proposition of carrying out a process with profit on a large scale. In laboratory experiments one often endeavors to get a high ampere-hour efficiency and watt-hour efficiency, and is satisfied if one obtains the same. In industrial operation it is the financial efficiency which should be made a maximum. Considered as a financial proposition, copper refining becomes a very complicated problem, as is evident from the recent paper of Mr. L. Addicks (Electrochemical Industry, May, 1904, page 180). Under these circumstances, the highest credit is due to the enterprise and energy of the Balbach Works in Newark, who were the first to put electrolytic copper refining on a thoroughly satisfactory and commercial basis in the United States.

While in 1879 an experimental plant for electrolytically refining copper was operated for a short time at Phœnixville, Pa., yet the first commercial refinery in America was built early in the eighties by Messrs. Balbach & Sons at Newark, N. J. Mr. Edward Balbach, Sr., himself an excellent chemical engineer, and his distinguished son, Mr. Edward Balbach, Jr., who is now the president of the Balbach Smelting and Refining Co., had the courage to undertake this pioneer work; they placed the development of the process into the hands of Mr. F. A. Thum, a chemist and metallurgist from Germany, who worked out all the details of the process with such success that only very small minor changes became necessary afterwards. The preliminary experimental researches were so successful that the Balbach Company decided to erect an electrolytic refinery on a large scale; this was completed in 1883, and since that time Mr. F. A. Thum has filled the position as superintendent of the plant, designed by him, up to today.

While at that time, there was already, among other smaller electrolytic refineries, that of Werner Siemens at Oker in the Hartz Mountains in Germany, yet they were tightly closed to any outsiders and absolute secrecy was kept concerning process and apparatus. It thus became necessary for Messrs. Balbach and Thum to work out independently all the details of their new plant. At the end of 1883 the Balbach Works produced from two to three tons of electrolytic copper per day, and the apparatus used at that time had been so well designed by Mr. Thum that, as was already mentioned, only some minor charges were made when the plant was enlarged as soon as the original output became inadequate. In fact,

the first electrolytic room installed by the company is still used to-day, and there are in it quite a number of tanks which have served their purpose successfully since the starting of the plant in 1883 and there is no essential difference between the original equipment and the present one, though the amperes employed have been increased from 1800 to 4500. The only change which has been made in the construction of the newer tanks is to make them a few inches higher in order to guard against short circuits, due to accumulation of the slimes at the bottom. All the principal arrangements have remained unchanged, although the capacity of the works has been considerably increased. The present output is about 45 tons per day.

The power plant which supplies current for the copper refinery contains three generators, the oldest of 120 kw. capacity is a Hochhausen machine, while two more recent machines, one of 100 kw. and one of 280 kw., were built by the Crocker-Wheeler Co. Fig. 1 shows a portion of the power plant of the copper refinery. The cross-compound Corliss condensing engines made by the Hewes & Phillips Co. are directly connected to the 280-kw. Crocker-Wheeler generator, which is mostly loaded with 300 kw., furnishing 4300 amperes at about 70 volts. Upon the gallery in the background of the cut is shown a dynamo, belt-driven by the large engine below; it furnishes current at 125 volts for lighting and motor driving about the works. For the electrolytic winning of silver a separate Crocker-Wheeler generator is installed which gives 1800 amperes at 35 volts.

FIG. 2.—APPARATUS FOR CASTING COPPER ANODES.

Copper Refinery.

There are in the whole, in the copper-refining rooms 440 electrolyzing tanks for depositing copper. Each tank contains 20 to 22 anodes and 20 to 22 cathodes, the plates being connected in multiple. The anodes, which are cast, as will be described below, have a size of 36 x 24 x 1¼ inches, and weigh from 300 to 400 pounds. The cathodes are thin electroplated sheets of copper of a size 36 x 24 inches. The current density used is 16 to 17 amperes per square foot, and the temperature of the electrolyte is maintained at about 50° to 60° C. (generally about 50° C.). The electrolyte is the standard copper sulphate solution, containing free sulphuric acid.

The tanks are arranged as shown in Fig. 3, giving a general view of the main copper refining room. As will be seen from this figure, the tanks are arranged in groups, each group consisting of two rows of tanks, so that always two tanks are placed side by side. All cathodes of the tanks in the left row are in the same plane as the anodes of the adjoining tanks in the right row, and vice versa. All the cathodes in the tanks are connected in multiple and so are the anodes. The various tanks are connected in series. In two side-adjoining tanks the cathodes of one tank are connected to the anodes of the other tank, thus accomplishing a series connection of the two tanks. Flat copper pieces used as supports form connectors and light covers protect the connections against the corrosive influnce of the solution in case any electrolyte is spilled when the plates are removed from the tanks.

All the tanks are on the same level. To provide for the necessary circulation of the electrolyte, each tank has its special outflow pipe and feeder pipe. If the outflow pipe is in one corner of the tank, the feeder pipe is provided in the corner diagonally opposite. Through the outflow pipe, the electrolyte flows off to launders placed below the boards on the floor on which the men stand in Fig. 3. The electrolyte is returned to the tanks from overhead launders through the vertical pipes shown in the same figure. Each of these pipes feeds four tanks, and for this purpose ends just above the point where the four tanks join together, and at its end the pipe then branches off into four pipes, which feed the solution into the four tanks.

All the tanks are in operation during the night, while during the day a certain number of tanks are regularly cut out of circuit and cleaned up. The treatment of the slimes which contain silver and gold will be described below. To prevent the solution from getting foul, a portion of the electrolyte is daily withdrawn from the tanks and fresh electrolyte is fed in. From the withdrawn electrolyte, the sulphates of copper and nickel are crystalized out one after the other, and the mother liquor is, according to its impurities, either put into use again, or is boiled down in cast iron vessels until the sulphates fall out as anhydrides which are dissolved in water and separated. The final sulphuric acid is very impure, and is sold to fertilizing works.

The method of casting the copper anodes is shown in Fig. 2. It is essentially a combination of Walker's standard casting apparatus with a special anode tilting mould of Mr. F. A. Thum. There are fourteen moulds arranged in a circle upon a turntable, which is revolved step by step, so that one mould after the other is filled with molten copper from the furnace shown in the back of the illustration. The moulds are normally in a horizontal position, and while the turntable with the moulds is revolved, the molten copper in the moulds gradually cools off. If necessary, water is sprinkled from above to accelerate the cooling off. When the mould reaches the point diametrically opposite to the point where the molten copper was poured into it a catch is released and the mould is tilted out of its horizontal position, as is clearly shown at the right hand in the front of Fig. 2. Mr. Thum's mould (U. S. patent 733,095, of July 7, 1903) is so constructed as to facilitate the removal of the cast anodes from the mould. For this purpose that part of the rim which forms the end face of the upper or suspension end of the anode (having the two lugs) is hinged to the main part of the mould. When the mould is tilted out of its horizontal position, the hinged part of the rim is swung away automatically from the bottom of the cavity of the mould and the anode-casting slides longitudinally out of the mould without meeting any obstruction. The anode drops on a moving platform, immersed in water, that carries it to a carriage which transports the anodes to the refining room.

FIG. 3.—ELECTROLYTIC COPPER REFINING ROOM, BALBACH SMELTING AND REFINING WORKS.

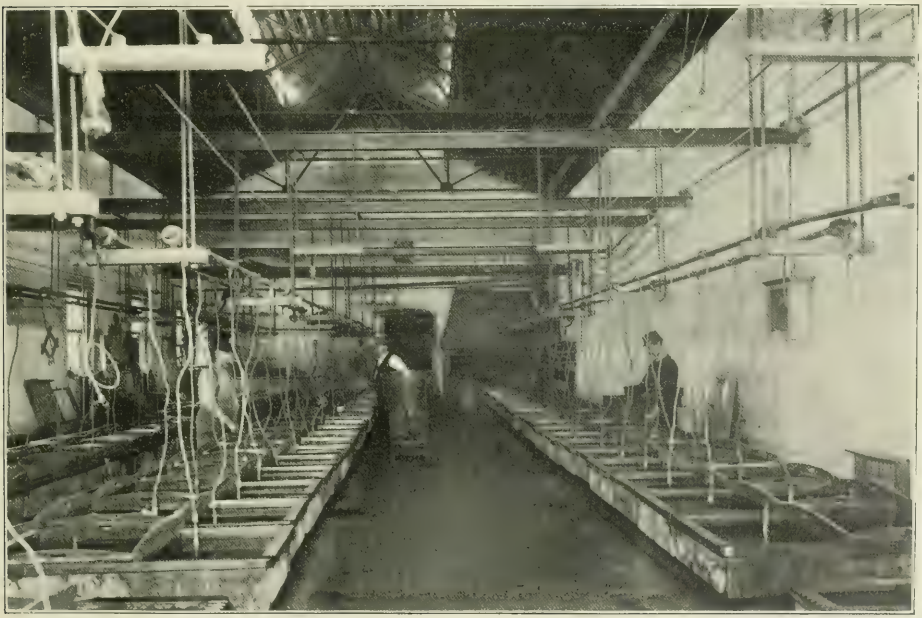


FIG. 4.—ELECTROLYTIC WINNING OF SILVER FROM THE SLIMES OF THE COPPER REFINERY.

Silver and Gold.

The anode slimes from the copper refinery contain silver and gold. They are regularly cleaned up, melted down, and the ore bullion obtained is parted electrolytically. The solution used for this purpose is dilute nitric acid, which soon changes to silver nitrate and copper nitrate. The copper accumulates in the solution, while the silver is deposited on the cathodes. The gold remains back in the anode mud and is therefrom recovered.

The electrolytic refining room for winning the silver is shown in Fig. 4. There are nine groups of tanks in series, each group containing ten tanks in parallel. The construction of each tank may be easily seen from the illustration. Each tank has a bottom of carbon which forms the cathode. Upon the carbon bottom rests a small silver plate from which connection is made to the negative overhead feeder. The silver is deposited in crystalline form everywhere on the carbon bottom, and is shovelled out at regular intervals.

The anode compartment consists of a wooden box which is placed into the tank, so as to fill about one-half of it. The right-hand row of tanks in Fig. 4 contains these wooden boxes in their right-hand half. These boxes have a slotted bottom, and their construction can be seen from the box leaning against the wall. Into the wooden box a cover of canvass is placed upon which rest the bullion plates which form the anodes and which are connected with the positive overhead feeder. The bullion plate gradually disintegrates, silver and copper going into solution, and the operation is carried on as indicated before.

Nickel.

In the years from 1894 to 1900 a method of nickel refining was operated at the Balbach works, very pure nickel being produced by an electrolytic process of Mr. Thum from nickel anodes, containing from 95 to 97 per cent Ni, bought from the Orford Copper Company. The details of the process have always been kept secret, although it is understood that two to three millions of pounds of pure nickel have been produced by this method.

For some time, nickel salts have also been produced as a by-product at the Balbach Works and sold to nickel platers. When the company refined blister copper from the Orford Works, the nickel which was originally contained in the copper anodes passed into the solution and accumulated there. When withdrawn, the copper sulphate was crystallized out and a nickel salt remained containing little copper. The latter was then removed by electrolysis.

THE RAPID MEASUREMENT OF THE CONDUCTIVITY OF COPPER ELECTROLYTES.

By Lawrence Addicks.

In making resistance measurements upon electrolytes, we must employ a method in which electrode effects are either absent or so small in proportion to the liquid resistance that they may be neglected. In the Kohlrausch method, if an alternating current of sufficient frequency is used, any such effects counter-balance one another, and the current is also rendered very small by making the cell one arm of a non-inductive bridge. By using induced currents, electrodes can be dispensed with altogether, but, in so far as the writer is aware, lack of sensitiveness has prevented the development of any useful method of this kind. In the liquid potentiometer proposed by Hering[1], the fall of potential in a column of electrolyte carrying a known current is balanced against a known electromotive force by varying the length of the column. At the moment of balance the potential electrodes are carrying no current. A potentiometer with Ostwald calomel electrodes might also be used[2]. Finally, we may treat the problem as if we had an ordinary metallic wire to measure and endeavor to choose the dimensions of the apparatus in such a way that the errors introduced are negligible.

The problem can be handled very satisfactorily by the last-named method, when the resistances of acidified solutions of a metallic salt, such as are used in the refining of metals, are to be measured, provided a precision of a couple of percent is sufficient. Some time ago the writer had occasion to measure a large number of such copper electrolytes, the solutions used being those ordinarily employed in copper refining. The Kohlrausch method proved rather tedious and Hering's potentiometer was tried with considerable success. There was difficulty, however, in getting a non-conducting cell of the shape required, at a reasonable cost, that would stand temperatures up to 90° C. without cracking or warping. The sliding electrode was difficult to keep in good condition in the presence of the corrosive liquid, and the expansion of the liquid in the open cell had to be reckoned with in the temperature coefficient runs. After some experimenting an adaptation of

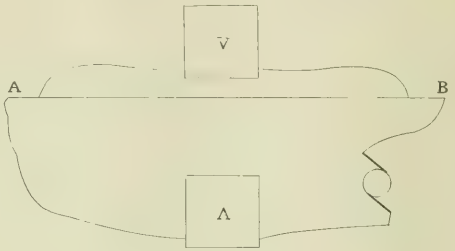


FIG. 1.—ARRANGEMENT OF TEST.

the Munich Shunt method for measuring currents in solid conductors was adopted, and, when the dimensions were properly worked out, the results agreed closely with those given by the other methods.

Figure 1 shows the usual connections for low solid resistances, the idea being to avoid including in the voltmeter circuit the drop of potential across the main current contacts, A and B. These contacts are, in a sense, analogous to electrode effects. Substituting an acidified solution of copper sulphate for AB, we have the following conditions to take care of. First, copper electrodes must be used throughout to avoid polarization effects as far as possible, and contamination of the electrolyte. Wherever current is led in by the copper electrode there will tend to be a gradually increasing concentration of the salt, and vice-versa at the cathodes. These differences in concentration set up counter electromotive forces, and also cause ohmic changes, as the resistance of a solution usually changes very rapidly with concentration. Therefore, the coulombs in the potential circuit during a test should be kept as low as possible. But we must keep the voltage well below the decomposition point of water to avoid any evolution of gas at the potential electrodes. We are limited by this consideration to pressures not exceeding, say, 1.3 volts. With a Weston voltmeter reading 0 — 1.5 volts, the resistance in the potential circuit will be about 150 ohms, and the current will therefore never exceed 0.009 amperes.

We may get this drop between electrodes any distance apart by suitably varying the dimensions of the liquid wire and the main current. This brings up a peculiar condition. The potential gradient between two electrodes, in solutions of the character under consideration at least, is much more steep in the region of the electrodes than would be expected. There is an ohmic resistance in the film next the electrodes that far exceeds in magnitude any counter electromotive force effects. To keep this from unduly weighting results the electrodes must be at least 25 cm. apart.

Figure 2 shows what enormous errors may be introduced

[1]Trans. A. I. E. E., XIX., 317.
[2]Trans. A. E. S., IV., 95.

by disregard of these facts. A represents the apparent specific resistance and temperature coefficient of a solution measured between electrodes only 4 mm. apart, and without special potential electrodes. B is for the same solution when measured in the apparatus being described.

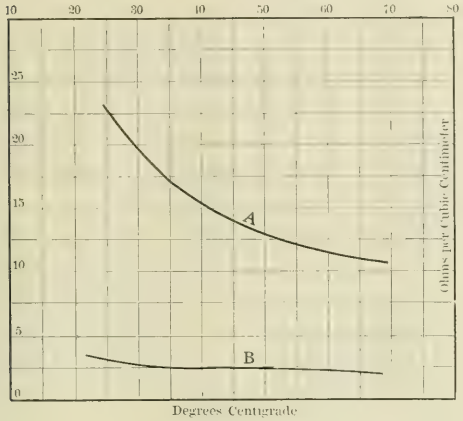


FIG. 2.—RESULTS OBTAINED WITH DIFFERENT ARRANGEMENTS OF THE TEST.

The length being fixed as 25 cm. we still have the diameter of the tube and main current to decide upon. 0.3 ampere can be conveniently measured to the precision desired on an ordinary milammeter. This current will require a diameter of

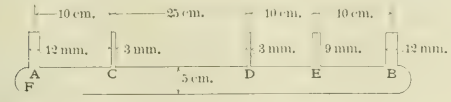


FIG. 3.—DIMENSIONS OF TEST TUBE.

about 5 cm. to give the necessary drop in 25 cm. length with the solutions to be measured. The dimensions of the glass tube employed are given in Fig. 3. The 0.3 ampere current enters and leaves at A and B. The potential leads are at C and D. E is for a thermometer and F is an opening to enable the apparatus to be emptied and washed without dismounting.

The connections are shown in Fig. 4. A current of 5 amperes is used for bringing the solution to the desired temperature, the reversing switch being thrown occasionally. This current suffices to bring the liquid to boiling in a few minutes.

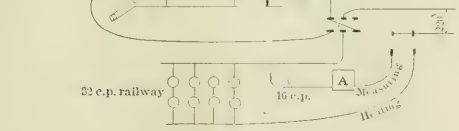


FIG. 4.—CONNECTIONS OF TEST TUBE.

The temperature is uniform throughout the tube to about a degree Centigrade, which is close enough for the results desired. Neglecting the expansion of the glass, the section of the liquid column is independent of the temperature. Experience has shown that no diaphragms are necessary between the current and potential electrodes, the distance between them being sufficient to prevent serious changes in concentration by diffusion. Readings are taken with the current flowing in each direction and should be identical. The current in the voltmeter circuit must be calculated from the drop across the voltmeter as shown by its own readings, and deducted from the main current. From Ohm's law and the dimensions of the tube we obtain the resistance per cubic centimeter. The characteristic curve of an electrolyte, as shown in Fig. 2, can be plotted in about twenty minutes.

For practical work in everyday operations, such as watching the effect of growing impurities, the apparatus has proved rapid, and sufficiently exact. The tube costs about a dollar and a half; the rest of the apparatus is to be found in any laboratory.

Perth Amboy, N. J.

APPLICATION OF THE ELECTRIC FURNACE TO THE METALLURGY OF IRON AND STEEL.

A very interesting paper on the general principles underlying the use of the electric furnace in the metallurgy of iron and steel, and on the different types of electric furnaces which have been devised for this purpose, was recently read before the meeting of the American Foundrymen's Association in Philadelphia by Mr. P. McN. BENNIE, of Niagara Falls. In the following we give a condensed abstract of this paper.

Mr. Bennie first discussed the various factors which have so far determined the location and growth of an iron-producing center (meaning the localities where are produced pig iron, steel, etc., and not necessarily finished products). Such factors are the existence of energy, in the form of coal, transportation facilities by rail or water, supply of iron ores, and facilities for getting the products to the market, as well as the nearness of the market. It seems that in general the location of iron-producing centers has been determined, not so much by the presence of iron-bearing measures, as by the presence of the energy necessary for the reduction and refinement, which in ordinary metallurgy is supplied by coal, coke and charcoal. Recently we have witnessed, it is true, a partial compromise in this respect, in the growth of iron industries in the vicinity of Buffalo, where the Susquehanna Co. and the Lackawanna Co. have erected enormous plants. But the location of plants there is due to the fact that fuel can be transported very cheaply from the Pennsylvania fields, while ores can be brought by water from the upper lakes at a minimum cost. Then Buffalo possesses unusually good transportation facilities to the consuming centers, by rail and water, through the great lakes.

If it should be possible to replace a portion of the carbon energy by electrical energy, derived at a relatively low cost from water power, or from the utilization of waste blast furnace gases, or from gases produced from anthracite culm, we may then expect to see metallurgical operations carried on under new conditions and industries spring up in new and unexpected places, with relation to supply of raw materials. Mr. Bennie was, however, careful to emphasize that it should not be imagined that the electric furnace will do anything that is demanded of it, or that it can be successfully applied under all sorts of conditions. That is a common error into which many have fallen who should know better. The electric furnace can do some things and do them better than any other kind of furnace, but it cannot do everything. From an economic point of view it is necessary to find out any of the particular cases the elecric furnace can be applied so as to offer advantages over other methods. It should be borne in mind that although electricity is the most flexible and tractable of the forms of energy, it is as a metallurgical agent generally the most costly. It should therefore only be employed with a thorough grasp of the conditions; and its use should be restricted to those applications where its superiority is clear.

Mr. Bennie then reviewed the progress made abroad and explained the peculiar reasons which have so far caused the progress to be greater abroad than in this country. He then gave a classification of the different purposes for which electric furnace methods have been applied in the iron and steel metallurgy. He distinguishes four classes, of which class 1 is designed as an adjunct to blast furnace working, class 2 as a partial dependent process, while classes 3 and 4 are entirely independent. These four classes are as follows:

No. 1. Treatment of molten pig iron as it comes direct from the blast furnace, for the purpose of refining and converting it into steel of certain grades. This may be called the electrorefining of steel.

No. 2. Treatment of cold pig iron, or a mixture of pig and suitable scrap, to produce iron and steel.

No. 3. Direct reduction of iron from its ores, and if desired, subsequent refinement into steel, as a practically continuous process, beginning with the raw ores.

No. 4. Production of various ferro-alloys, by either of the following methods:

(a) Starting with a mixture of iron ores and ores of the metal to be alloyed, or

(b) Starting with a mixture of pig iron and minerals to be reduced and alloyed therewith.

The lecturer pointed out the characteristic features of these four classes as follows:

Class 1. Treatment of molten pig iron direct from blast furnace.—The electrorefining of molten pig iron direct from blast furnaces, or cupolas, presents certain advantages over treatment of cold metal. For instance, the considerable amount of heat contained in the hot metal is utilized. Also, hot iron has a higher electrical resistivity than cold iron, so that when it is desired to conduct electrical refining by producing the required temperature by Joulean heat, this is more easily carried out by starting with hot metal. For refining purposes, furnaces of the resistance type seems well adapted; that is, where the temperature of the bath is maintained by the generated heat of an electric current passing through the metal itself.

Class 2. Treatment of pig iron, or pig iron and scrap, starting with the metals in the cold state.—The class of electrical furnaces employing this method comprises those in which the high temperature of the electric arc is used to start the process, and later when a sufficient quantity of molten metal has been produced in the hearth, the current is made to pass through the slag floating on top of the bath. The slag has a higher resistivity than the molten metal, and the heat thus generated is taken up by the fluid metal beneath.

Class 3. Direct reduction from the ores.—Processes starting with the ores themslves do not seem destined to wide application in the United States. In the present state of development of electrometallurgy, furnaces can be designed for but limited capacities, compared with modern blast furnaces, and it is doubtful if pig or even steel could be produced in electrical furnaces at a sufficiently low cost to justify this class of operations. Where it is desired to refine the reduced iron into steel, as part of the process, it possesses a greater interest.

Class 4. Production of ferro-alloys.—This class of furnaces has been applied for a number of years with considerable success, and its value for the purpose is undeniable. It already occupies a permanent place in the metallurgical scheme, as steelmakers are dependent upon electrical methods for many ferro-alloys not otherwise obtainable, such as ferro-silicon having a high percentage of silicon, high-grade ferro-manganese, ferro-chromium, ferro-alloys of titanium, molybdenum, tungsten, vanadium, etc.

From the electrical point of view the various styles of furnaces are divided by Mr. Bennie into the following:

(A) *Electric arc furnaces.*—In this class of furnace, carbon electrodes are used, the heat being generated in the arc itself and absorbed by the material beneath, which is generally out of actual contact with the arc. For this class of furnaces, those of Ernesto Stassano and Ramon Chavarria-Contardo may be considered as typical.

(B) *Arc-resistance furnaces.*—In this class carbon electrodes are employed to convey the current to the mass under treatment. An arc is general used to start the bath, when the current is passed through the molten material, or through a layer of slag floating on top of the bath, according to the disposition of the electrodes. To this class belong the furnaces of Charles Keller, Paul Heroult, M. Harmet and E. A. Sjöstedt.

(C) *Resistance furnaces, with granular resistance.*—There are not many examples of this method of generating heat, although it certainly offers distinct advantages peculiar to itself. Paul Girod seems to have made the most progress with this type.

(D) *Resistance furnaces, by direct heating.*—These are refining furnaces, without carbon electrodes. In this class of furnace, as in the preceding class, an effort is made to dispense entirely with carbon electrodes in contact with the bath, to avoid introduction of carbon from the electrodes. Gustave Gin has developed one style of furnace of this kind, in which heavy currents are passed through the molten metal and the Joule effect is utilized to bring the material to the desired temperature.

(E) *Refining furnace heating by induced currents.*—In this type of furnace the heat is produced by induction, using the material as the secondary in a transformer. The credit for working out this ingenious type belongs to F. A. Kjellin, of Gysinge, Sweden.

Mr. Bennie then gave a review of various types of furnaces which have been used in practice on a more or less large scale and first dealt with electric furnaces, describing the Stassano furnace. (Electrochemical Industry, vol. 1, March, 1903, page 247.) The author stated that while the original company exploiting the Stassano process was compelled to suspend work on account of lack of funds, yet the Italian Government agreed to give Capt. Stassano further assistance, so a furnace of about 125 hp. was built at the Royal Foundry Arsenal in Turin. This furnace was started on June 14, 1903, and, according to recent advices, is capable of turning out 2500 to 3000 kgs. of metal per day, with 120 to 140 hp. The quality and yield are stated to be much improved over previous tests. One thousand amperes are employed at 80 volts. The production is at the rate of 55 pounds per horse-power day.

Ramon Chavarria-Contardo, at Paris, is also working with a furnace employing radiated heat from the arc, but no data are available as to the product. The general construction of the furnace, as seen by Mr. Bennie, is similar to Stassano's.

The author then discussed resistance furnaces in which electrodes are plunged into the materials to be reduced and fused. Generally the process is started with a small quantity of material and an arc is sprung which quickly reduces the materials to a fluid state. Further material is added until finally the furnace body is comfortably filled, when fusion goes on quickly and continuously. In most cases when the furnace is under full way, the electrodes are maintained at the level of the layer of slag flowing above the liquid bath. As an example, Mr. Bennie described the Keller process (see Electrochemical Industry, vol. 1, January, 1903, page 162; vol. 2, July, 1904, page 280).

The author then dealt with the Harmet process. Mr. H. Harmet, who is chief engineer of the Société des Fonderies, Forges et Acieries, of St. Etienne, France, has designed several types of furnaces for the electric treatment of iron ores, some being partly electrical and others wholly electrical. Mr. Bennie remarked that Harmet is essentially a metallurgist and his furnaces show that he looks at the problem through the eyes of the metallurgist rather than the electrical engi-

neer; that it is easy to trace in his designs the influence of blast furnace practice. (Furnaces patented by Harmet were described in Electrochemical Industry, vol. 1, 1903, page 422, 587 and 588.)

Some estimates have been published on the Harmet process, giving a cost of $5.60 per ton. Mr. Bennie remarked that this figure is wholly misleading, since Mr. Harmet himself has stated that about 3600 hp.-hours are required by this process to produce one ton of steel from the ore. Taking the average horse-power-year as 8000 hours, allowing for stoppages, 3600 hp.-hours equal about 0.45 hp.-year, which at $12 per year

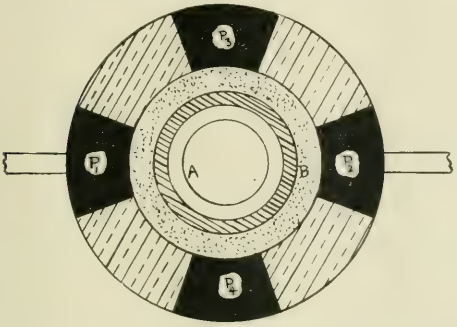


FIG. 1.—HORIZONTAL SECTION OF GIROD STEEL FURNACE.

$P_{1\,2\,3\,4}$ are the electrodes, A the crucible, B the granular resistance material.

would be about $5.40 alone for electrical energy, and it is doubtless to the power cost that the above published figure of cost refers. M. Harmet's process is being studied by himself in conjunction with Mr. Paul Girod, of Albertville.

The author then discussed the Heroult process (see Electrochemical Industry, vol. 1, pages 63, 287, 449, 461 and 467), and then passed over to the Sjöstedt furnace (Electrochemical Industry, vol. 1, June, 1903, page 353; vol. 2, April, 1904, page 153, and May, page 188 and 207). Mr. Bennie remarked that outside of a few minor details, as to cooling arrangements, etc., the furnace used by Sjöstedt does not differ materially from the Siemens electric furnace in use ten years ago; it rep-

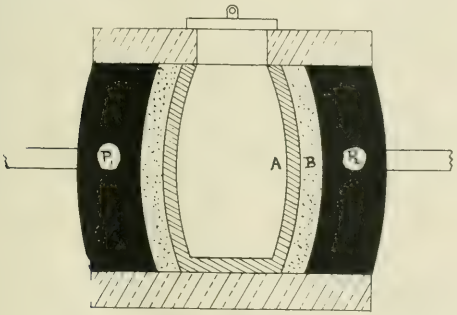


FIG. 2.—VERTICAL SECTION OF GIROD STEEL FURNACE.

resents a type that has been thoroughly tried by several electrometallurgists and abandoned as being very inefficient; better results would no doubt be obtained on a larger scale and by using a more highly developed type.

The author then passed over to another type of furnace that is a resistance furnace with superficial resistance. Mr. Paul Girod, electrometallurgist to the Société Anonyme Electrometallurgique, at Albertville, Savoie, France, has devised a furnace which consists of a crucible made of refractory material, surrounded by a resistance of graphite, in granular form, or even agglomerated. The carbon electrodes are placed equidistant around the resistance material surrounding the crucible; between the carbon electrodes refractory bricks are fitted. Refractory material for thermal insulation is also placed below and above the crucible, with an opening for charging and discharging purposes.

The whole is mounted on trunnions so that it can be oscillated or tilted even while running. These furnaces are of about 200 hp. each, with a normal pressure of 0.25 volts. By this method very uniform heating is obtained. It is possible to fuse easily bronze, steel and other metals. Its use has also been suggested for glass, for which it seems peculiarly adapted.

The temperature can be maintained at 500° C., if desired, but can also be raised to 3500° or 4000° C. In fact, in such furnaces, Girod has been able to fuse pure vanadium and ferro tungsten, which are fused only with the greatest difficulty. These furnaces, of about 150 kw., are said to produce 2000 kgs. or 4400 pounds of steel per day. In addition to the works at Albertville, another factory was started several months ago at Courtepin, near Fribourgh, Switzerland; they also have a third works at Ugine, France. This looks like a permanent entry of electrometallurgy into the industry of steel manufacture.

The author then went over to a discussion of the Gin process (Electrochemical Industry, January, 1904, page 20), and of the Kjellin process (Electrochemical Industry, vol. 1, December, 1903, page 576), and made a brief reference to the very original process of Marcus Ruthenberg (Electrochemical Industry, vol. 1, page 58, 84, 202, 482, 494).

In summing up, Mr. Bennie said that the electrometallurgy of iron and steel has already left the domain of the laboratory and experimental plant, and taken on the serious aspect of an established industry. The electric furnace has its limitations, which it would be well to bear in mind. Even its most ardent advocates do not consider it a menace to the older methods, but rather as a new and useful adjunct to present metallurgical practice. It should be noted that while some processes are designed to perform the *direct reduction* of iron ores, the general tendency is to use the electrical energy for production of steel, and particularly as a refining agent in treatment of pig iron and scrap. For this field of usefulness, the electro-refinery seems destined to occupy a permanent place in the art.

When we shall witness the combination of the blast furnace for cast iron; the Bessemer converter for common steel, and

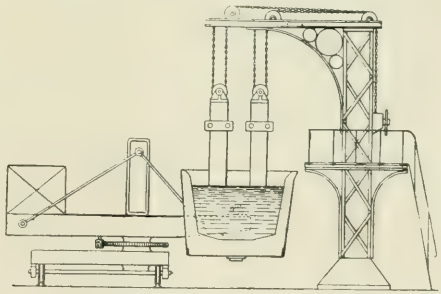


FIG. 3.—THE ELECTRIC REFINING FURNACE AS AN ADJUNCT TO FOUNDRY PRACTICE.

the electrical refinery using energy generated from waste blast furnace gases, making higher grade steels, then industrial metallurgy will have attained the high-water mark in the utilization of the heat energy of coal. In attacking the older art from the crucible steel standpoint, electrometallurgists are undoubtedly hitting at the weakest spot.

In conclusion, Mr. Bennie makes some reference to the application of the electric furnace to foundry practice. Take a

foundry with a number of cupolas. It would be possible to arrange an electric refining furnace so that it could use the product of any one or of all of the cupolas. The author exhibited an illustration showing how this could be done. He has a furnace body in the form of a ladle, placed upon a carriage, suitably counter-balanced, and able to swing free in a circle. It may receive its charge and then be placed under the arrangement for carrying electrodes. By lowering the electrodes and turning on the current, refining is carried out. Without using excessive currents, liquid iron may be converted into steel of good quality.

Mr. Bennie offered this to the enterprising foundry managers as a suggestion of ways for employing their full capacity at all times; for improving the quality of their castings, for converting a portion of their product into steel. For a small cost, a foundry arranged for the manufacture of cast iron could undertake steel castings and augment considerably its sphere of commercial activity. The author remarked that many foundries are already equipped with electric power, and that in discussing the matter with a well-known central station manager he was assured that the station would welcome any proposition which would take power during their periods of light load, say from 10 p. m. to 1 p. m. next day, and could make very low rates for such intermittent power to be taken at definite times.

The author gave a final word of warning, however. The construction of electric furnaces is not a small matter. Results of a kind can be obtained by throwing four walls together and sticking a couple of electrodes in and calling that an electric furnace. Satisfactory results require careful treatment in all the phases of electric furnace construction and operation, as well as considerable experience. Many processes have been failures, due simply to the fact that those who tried them did not understand electric furnaces and had developed a thoroughly inefficient practice. Money is saved in the end by a thorough understanding of what one is going to do before doing anything.

A CONTRIBUTION TO THE THEORY OF THE JUNGNER-EDISON ACCUMULATOR WITH CONSTANT ELECTROLYTE.

By M. U. Schoop.

(*Concluded from page 276.*)

IV.

The changes of volume caused by the passage of the current are considerably greater for the nickel electrode than for the iron or cadmium electrode, as was already noticed. If the reaction which takes place at the active nickel material during discharge consists simply in oxygen being given off (at the rate of 0.3 gram per ampere-hour), we might expect a corresponding diminution of weight. The experiments prove, however, that on the contrary the nickel electrode, when weighed in the electrolyte, gets heavier during discharge with any current whatsoever and gets lighter during charge. This surprising fact is caused by the contraction of the nickel material, or, in other words, the specific weight of the active mass of nickel increases during discharge and a smaller amount of electrolyte is now displaced by the plate than before. The absolute weight of the nickel plate decreases, of course, during discharge, and that of the iron plate increases by the same amount. This can be proven by conducting the experiment in the manner mentioned before, by removing the plates after the test from the containing vessel and placing them on the scales. Such a measurement, however, of the absolute changes of weight does not give any information as to the changes of volume of the active materials which have taken place or as to the concentration changes of the solution. This is evident, for instance, from the following experiments.

The nickel electrode, after having been fully charged, was left at rest for two days, so that any concentration differences existing in the cell should be annihilated. The nickel electrode was then removed from the vessel, the solution was washed off from its surface under a spigot, and the electrode was dried at its surface by means of blotting paper and placed on the scale. The plate weighed 214 grams. It was then placed in a cell which was discharged. After 11.7 ampere-hours had been taken out and the cell had been left at rest for 16 hours, the nickel electrode was handled in the same way, the manipulation requiring not more than 2 minutes, and the weight was again determined and found to be 224.7 grams, which means an increase of weight by 40.7 grams. The decrease of weight due to the removal of oxygen is $0.3 \times 11.7 = 3.51$ grams, and is therefore more than counterbalanced by the increase of volume of liquid in the pores during discharge. It is also possible that in spite of the long period of rest the existing concentration differences in the solution had not been completely annihilated.

A similar experiment with an iron electrode from which 10.5 ampere-hours were taken during discharge, gave an increase of weight of 4.4 grams, instead of $10.5 \times 0.3 = 3.15$ grams. In both cases the agreement between calculation and experiment is poor. The difference between the measured and calculated value is not as great with the iron electrode as with the nickel electrode; it may again have been mainly due to an increase during discharge of the volume of the pores filled with liquid. After a few experiments, no further tests were made by this method, since the prospects of getting results which would agree with each other were very poor.

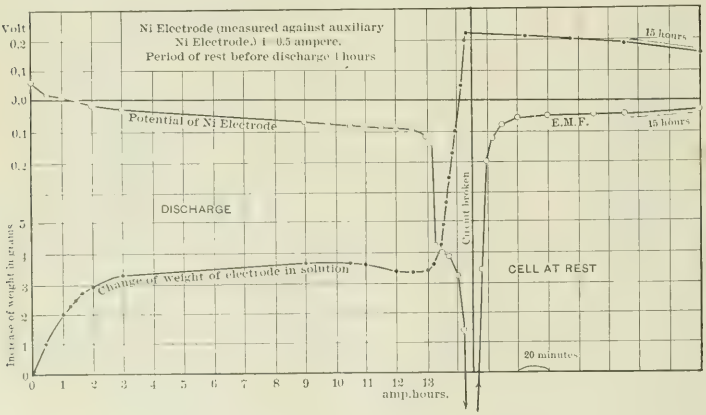


FIG. 5.—DISCHARGE OF Ni ELECTRODE WITH 0.5 AMPERE.

Discharge of Nickel Electrode with 0.5 Ampere.

For the auxiliary electrode (through which no current passes, but which is simply used for determining the potential) the same small nickel electrode was used as in the former tests. For the sake of simplicity its potential is taken as zero in the diagramatic representation of the results in Fig. 5. The potential of the nickel electrode shows the features characteristic for this type of electrode. At the beginning of discharge, for the first ampere-hour, the curve is above

the axis of zero, *i. e.*, the potential of the nickel electrode under test is higher than potential of the auxiliary electrode during the first two hours of the discharge with 0.5 ampere. After that time the curve goes down slowly and continuously, and when 13 ampere-hours have been taken out of the plate the potential — 0.13 volt is reached. An extremely steep voltage drop now occurs, the potential dropping in a nearly perpendicular line down to — 0.5 volts. During the next two hours (corresponding to one ampere-hour) the voltage continues to drop, first more slowly but then drops again rapidly. The value which was finally reached is — 1.325 volt, the electrode being about to be reversed in polarity. The current was then interruped, and the change of e. m. f. observed afterwards is shown at the right-hand of Fig. 5. Like in the lead accumulator, the curve is a logarithmic one, but is much less rounded. The potential reached after one hour is — 0.05 volt, and after 15½ hours a constant value — 0.03 volt is reached.

With respect to the change of weight the nickel electrode behaves in a very peculiar way, as was already noticed. The weight of the plate in the solution increases quickly at the beginning of the discharge, until about three ampere-hours have been taken out of the plate. For a considerable time afterwards, the variation of weight is small. After eleven ampere-hours a slight, but perfectly evident, decrease of weight is observed. Then, in the moment when the potential undergoes its rapid drop, an enormous increase of weight is observed, caused by the contraction of the active material. The plate suspended on the balance now increases so quickly in weight that the motion of the balance beam may be observed with the naked eye. After 14.3 ampere-hours the increase of weight was 11.2 grams. The discharge circuit was then broken and the change of weight of the electrode was observed while the cell was at rest. As the curve shows, diffusion annihilates the existing concentration changes and causes a very slow but continual variation of weight. After ninety minutes a decrease of weight of only 0.3 grams is observed, and after fifteen more hours the decrease of weight is still only 0.4 grams.

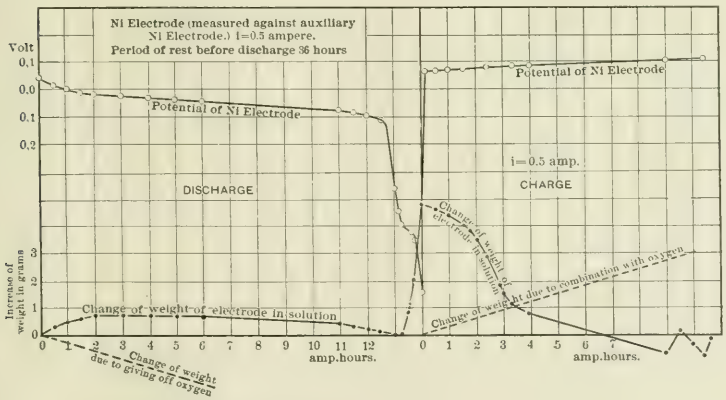

Ni Electrode (measured against auxiliary Ni Electrode.) i=0.5 ampere.
Period of rest before discharge 36 hours
Volt
0.1
0.0
0.1
0.2
Potential of Ni Electrode
Potential of Ni Electrode
DISCHARGE
i=0.5 amp.
CHARGE
Change of weight of electrode in solution
Change of weight due to combination with oxygen
Change of weight of electrode in solution
Increase of weight in grams
0 1 2 3 4 5 6 7 8 9 10 11 12
amp.hours.
Change of weight due to giving off oxygen
0 1 2 3 4 5 6 7
amp.hours.

FIG. 6.—DISCHARGE AND CHARGE OF Ni ELECTRODE WITH 0.5 AMPERE.

After twenty hours' rest it was tried to continue the discharge of the plate with 0.5 amperes, but the plate appeared to be absolutely exhausted since the potential dropped immediately to zero.

The "electrochemical fatigue" of the nickel electrode has therefore a character essentially different from the "fatigue" of the lead accumulator which has been designated by Dolezalek as concentration polarization or exhaustion of electrolyte. The slow decrease of voltage has little to do with concentration changes of the solution in the pores; this appears to be proven by the form of the weight curves.

Concerning the peculiar form of the curve of change of weight, it is to be remarked that it is not absolutely free from criticism in so far as the period of rest which was interposed between charge and discharge was only four hours, and, as found by later experiments made for this purpose, this period is not sufficient to annihilate all concentration changes produced during charge. I regret that in some of my experiments this fact was not sufficiently taken into consideration since I first had assumed without proof that sufficient uniformity of concentration in all parts of the cell would be reached within a few hours.

The same experiment was therefore repeated, but after the cell had been charged it was left at rest for more than thirty hours. The results are given in Fig. 6, and show clearly the different composition of the liquid in the pores at the beginning of the discharge in the two cases. It is, perhaps, superfluous to remind the reader that the absolute changes of weight of the solid portions of the electrode are exactly the same in both cases, and that the difference of the two weight curves is produced only by the difference in the diffusion phenomena. We know that during charge the liquid in the pores of the iron or cadmium electrode becomes more concentrated and that in the pores of the nickel electrode becomes more dilute. At the end of the charge, the active nickel material is therefore impregnated with dilute solution, so that the relative change of weight of the electrode in the solution during discharge will be more or less evident, according to the degree to which the concentration of the solution has already become uniform at the beginning of the discharge, and this degree depends on the length of the period of rest interposed between charge and discharge.

It is very peculiar that the variation of weight in Fig. 6 changes its sign towards the end of the discharge, *i. e.*, after a certain number of ampere-hours there is no longer an increase of weight, but a decrease of weight. The same observation is made again and again at low discharge rates, while for higher discharge rates the influence manifests itself in so far as the rising weight curve becomes more or less flattened. Qualitatively the weight curves during discharge in Figs. 5 and 6 are not different, while the potential curves during discharge are exactly the same.

In the test represented in Fig. 6, the discharge with 0.5 ampere was followed immediately by a charge with the same current. In general the results which are obtained by my method are less reliable during a charge than during a discharge. The reason is that during a charge gas bubbles are soon developed (which accounts for the low efficiency of the nickel iron accumulator). These gas bubbles are, of course, sources of error in the weighing. At the beginning of the charge, the voltage undergoes a rapid increase and increases then slowly and continually in a straight line from + 0.06 to + 0.11 volt. The weight curve for a charge does not show that sudden bent which is the characteristic feature of the weight curve during discharge. This proves that the change in the different states of oxidation does not set in immediately. The weight curve would probably show a picture analogous to the discharge weight curve, if after completed

discharge the cell was left at rest for a sufficient period, so as to produce uniformity of concentration. The irregularities observed in the diagram at the end of the charge are due to gas bubbles.

Discharge with 15 Amperes.

From the large number of experiments made with the suspended nickel electrode, I will also give the results obtained for a discharge with 15 amperes. During discharge the liquid in the pores of the nickel electrode becomes more concentrated, while it gets more dilute during charge, and these concentration changes will be the greater the higher the rate of discharge or charge; it is therefore to be expected that this manifests itself in the curve of the change of weight. In fact, the experiments prove the correctness of this conclusion. It is to be remarked, however, that the real picture of the diffusion phenomena at the electrode is probably somewhat covered by the fact that at high current densities a considerable increase of temperature takes place at the electrode. This causes an expansion of the plate which must manifest itself in a decrease of weight of the suspended electrode in the solution. The heat effect is the sum of the Joulean effect, i^2r, the dilution heat at those places where concentrated solution is in contact with dilute solution, and finally the heat liberated by the exothermic reaction. In this experiment, as in those made with a low discharge rate, it was found that it is necessary to leave the cell at rest after completed charge for quite a long period before it is discharged, as otherwise the results obtained do not agree with each other.

The discharge curve of the nickel electrode at 0.5 ampere is not dissimilar to that of a lead peroxide plate, if, in the case of nickel, we do not consider the last small portion of the curve. For a discharge at the high rate of 15 amperes, this is no longer the case. The curve here consists of several straight lines which can be sharply distinguished from each other. The first drop of voltage at the beginning of the discharge is now more rapid and the whole curve is much more declined than before; this is only natural, since the capacity is now smaller. Exactly after 10.2 ampere-hours the current was interrupted and the changes of e. m. f. (measured against the small auxiliary nickel electrode), as well as the variations of the concentration of the electrolyte were observed. The results are given in Fig. 7.

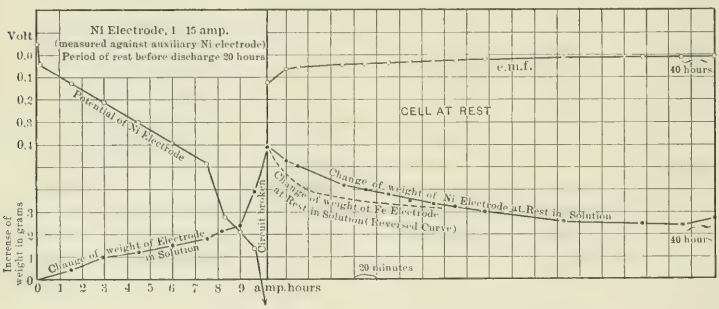


FIG. 7.—DISCHARGE OF Ni ELECTRODE WITH 15 AMPERES.

The curve giving the increase of e. m. f. after the conclusion of the discharge is similar to the former curves. After six hours a constant value of — 0.01 volt is reached. It is interesting to compare the forms of the e. m. f. curves after the completion of the discharge while the cell is at rest, for the nickel and the iron electrode. A comparison of the two curves of the variations of weight while the cell is at rest for the nickel and iron electrodes is also instructive.

With the iron electrode, after the discharge has been discontinued, a rather quick increase of weight takes place, caused by solution of normal concentration rushing from the outside into the pores of the plate. With the nickel electrode the reverse phenomenon takes place, the weight decreasing on account of diffusion of concentrated solution from the pores of the plate to the outside solution of normal concentration.

To enable an easy comparison of the speed of diffusion for the iron electrode with that for the nickel electrode, the weight curve for the iron electrode (while the cell is at rest) is taken from Fig. 3 (page 275 of July issue) and plotted in Fig. 7 in form of a dotted curve; to make the comparison of the speeds of diffusion easier this curve is plotted reversed, that is, the dotted weight curve of the iron electrode in Fig. 7 represents an increase of weight, while the weight curve of the nickel electrode represents a decrease of weight.

Under the supposition that the mean concentration of the electrolyte remains unchanged as to its contents of KOH during the passage of the current—which is certainly a justified assumption—we may conclude that the concentration of the solution in the pores of the one electrode increases in exactly the same degree as it decreases in the pores of the other electrode, and vice versa. One might, therefore, perhaps expect that after completion of a discharge, made under otherwise equal conditions, the weight of the nickel electrode should decrease by exactly the same amount as the weight of the iron electrode increases. However, in such a conclusion one overlooks that the changes of the volume of the two active masses are very different, and this explains why the experiments show that (even after discharges of the same number of ampere-hours) the equalization of concentration by diffusion is not represented by identical curves for the iron and nickel electrode. Moreover, it is possible that so-called concentration currents occur also with the electrodes of the alkaline accumulator, and that they influence more or less the speed of diffusion in a similar way as in the lead accumulator according to the researches of Dolezalek.

The change of the volumes of the active masses of nickel and iron electrodes may also be observed in such a way that a small accumulator is enclosed in a containing vessel and the volume changes, due to the discharge of one ampere-hour, are read directly on a calibrated capillary tube connected to the top of the containing vessel. During the experiment, the apparatus is preferably placed in a large water bath of constant temperature. I found in this way a decrease of volume of 0.16 cubic centimeter per ampere-hour discharge. But it may be emphasized that this value refers only to the slow voltage drop which is of practical importance, and I do not claim that this figure is very exact. After the sudden drop of voltage, the column of liquid in the capillary tube dropped very quickly below the calibrated scale so that further readings were impossible. Dolezalek found by a similar experiment for the lead accumulator an increase of volume of 0.42 cc. per ampere-hour discharge. (Dolezalek, The Theory of the Lead Accumulator, translated by C. L. von Ende, page 104.)

I like to call attention to the following experiment. Although it does not belong to the series of tests under discussion in this paper, yet it is very suitable to emphasize the very different behavior of the lead accumulator and alkaline accumulator with respect to diffusion. If two lead peroxide plates which are discharged to one-third, are connected, as shown in Fig. 8, and if a current is sent through this system in a certain direction, the following observation is made when the charging circuit is broken and the two electrodes are

short-circuited through an ammeter. The ammeter shows a very strong current which is directly proportional to the concentration difference between the concentrated acid in the pores of the charged electrode and the dilute acid in the pores of the discharged electrode. This concentration difference, and therefore the current observed in the ammeter, will be the stronger the greater the current was which was sent through the system before. The short-circuit current is, of course, a maximum at start and decreases rapidly and continually until no longer any concentration difference exists between the acids in the pores of the two plates.

If the same experiment is made with charged nickel electrodes, they show an entirely different behavior. Under exactly the same conditions of the experiment (with equal dimensions of the plates and equal currents) the short-circuit current is smaller for nickel electrodes than for lead peroxide electrodes; moreover, the curve of the short-circuit current indicates that in this case the short-circuit is due less to the different concentrations of the solutions in the pores, but rather to different states of oxidation of the two nickel masses. The correctness of this conclusion may be proven, if, before we short-circuit the electrodes through the ammeter, a long period of rest is inserted during which the changes of concentration disappear. In spite of this period of rest, a strong short-circuit current is observed with the nickel electrodes, while with the lead peroxide electrodes, the short-circuit current completely disappears under the same conditions. The curves in Fig. 9 give the results of such comparative tests and do not need any further comment. It may be remarked that KOH solution and sulphuric acid of maximum conductivity were used and that the plates of nickel and lead had approximately the same capacity.

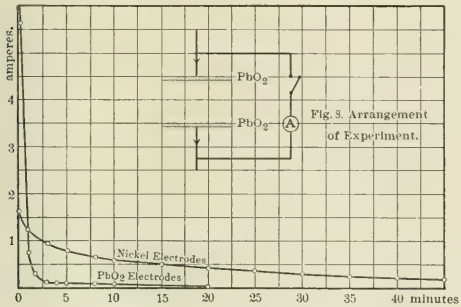


Fig. 8. Arrangement of Experiment.

FIG. 9.—CURVES SHOWING DIFFERENT BEHAVIOR OF NICKEL AND LEAD PEROXIDE ELECTRODES.

* * * * *

The results of the experiments described in this paper may be briefly summarized as follows:

(1) The method of measurement, using an electrode suspended on a scale, enables one to study the changes of volume of the active masses of the electrodes and the diffusion phenomena during and after the passage of the current.

(2) The changes of volume are greater for the active nickel mass than for the active iron mass, and they are the greater the further the discharge is pushed.

(3) Roeber's theoretical conclusions were confirmed by the experimental investigation. At both electrodes, strong concentration differences are produced during the passage of the current, while the concentration of the free electrolyte between the plates, as well as the average concentration (*i. e.*, the total content of KOH in the electrolyte) remain constant.

(4) During the discharge the solution becomes more concentrated in the pores of the nickel electrode and becomes more dilute in the pores of the cadmium or iron electrode; during charge the opposite effect is observed.

(5) A so-called concentration-polarization, *i. e.*, exhaustion of the electrodes due to dilution of the solution in the pores (corresponding to the exhaustion of sulphuric acid in the lead accumulator) seems to exist to considerable extent in the iron electrode. The iron electrode, therefore, shows a "recovery" of potential (increase of e. m. f.) after the interruption of the current, due to the diffusion of the electrolyte into the pores of the plate. It is probable that the increase of temperature has also an essential influence on the capacity of both electrodes.

(6) The measurements appear to justify the conclusion that the alkaline accumulator with constant electrolyte has a higher temperature coefficient than the lead accumulator, and that the temperature coefficient is positive.

* * * * *

Postscript.—The nature of the reactions at the Fe and Ni electrodes during electrolysis is not yet exactly known. Especially the supposition that at the cathode iron is dissolved would be in contradiction to the observations of Hittorf on the passivity of iron. The ionic reactions may perhaps be written $Fe \rightarrow Fe^{\cdot\cdot}$ and $Fe \rightarrow Fe^{\cdot\cdot\cdot}$, besides formation of Fe_3O_4. The ionic reaction at the anode seems to be $Ni^{\cdot\cdot\cdot} \rightarrow Ni^{\cdot\cdot}$. According to measurements of Prof. F. Foerster (as communicated to me in a private letter) the temperature coefficient is positive and is about 0.0007 (in the average) for one degree between 0° and 30° C. The e. m. f. therefore increases with the temperature. The temperature coefficient was found to be independent of the concentration. This agrees with Jungner's theory, which requires that the electrolyte remains constant.

Cöln-Lindenthal, Germany.

AN INDEX TO ELECTROCHEMISTRY AND ITS APPLICATION.

At the last meeting of the American Electrochemical Society in Washington, a paper was presented by Mr. Adolph L. Voege, formerly an engineer of one of the Niagara electrochemical concerns and now a resident of Zurich, Switzerland, on a card index for electrochemistry and its application. Mr. Voege's paper was submitted to the Society with a letter from Prof. W. D. Bancroft, who recommended the scheme of Mr. Voege to the attention of the members of the Society.

On account of limitations of time, the paper was not read at the meeting and for this reason we were unable to give an abstract of the same in our report in the May issue. The paper has now been printed in the fifth volume of the Transactions which has recently been issued. Since Mr. Voege's intentions certainly deserve the interest and support of all interested in elctrochmistry, we give his paper, which was prepared by him in collaboration with Dr. H. H. Field, the director of the Concilium Bibliographicum in Zurich, nearly in full as follows:

When a piece of scientific experiment is undertaken at a university to-day, the advice is to devote two-thirds of the time to the literature of the topic. The detailed study of the works of predecessors must obviously be done personally; but no one who has made the attempt will fail to appreciate the enormous difficulties that exist to-day in finding out what has been published the world over on any given topic. And yet let the student overlook one single reference, published, perhaps, in a foreign tongue and in an obscure journal, and he may suddenly awake to the desolating realization that his long months of study have been useless and that he has merely rediscovered a fact long since known. Perhaps the overlooked paper may contain suggestions which, if known in time, would have given a totally different trend to his work, so that he falls short of discovering vital features and finds that his labor has been almost useless; he may even find that another, better posted on what has already been done, has with far less pains come to valuable results, which would have been his, had he only learned in time of that earlier work. A

manufacturer sees a by-product more or less wasted, when, perhaps, in some other land this same product is turned to good acount. Who has such encyclopædic knowledge that he can advise him? Think of the inventors who are wasting their lives by not being able to know in time the partial solutions their problems have already received. Who can tell how many unforseen applications may be made of a process devised merely to meet one special need?

These are things that individual effort can never attain. Here organization is the salvation—a central agency where the work will be done once for all. Personal conviction and the advice of leaders in electrochemistry brought this need home to the author some time ago, and he resolved to devote his life to the task, if he could only count on the support of the very persons who would be benefited by his work. It is evident that foreign work is least known in America, and during the author's stay in Germany, he set to work to gather all the information possible in the great libraries. Later, chance brought to his knowledge the fact that zoölogists had met similar needs by an organization such as he had planned, and that the same was in successful operation in Zurich, Zwitzerland, under the name of Concilium Bibliographicum. It seemed at once to the author that if a theoretical science such as zoölogy could find advantage in such an institution, this must be still more the case for a science where great financial interests are involved, and he found, on studying the methods used in the Concilium, the best possible illustration of the time-saving that such work will yield. Here he had been independently working on this question only to find the problems and methods already solved and to such perfection that he could take a new start from what had already been done.

No book index can possibly serve the purpose. In a growing science a book becomes out of date while it is going through the press. It cannot be corrected, it cannot be expanded. Alone the card system, in which each work as it appears is indexed on a separate card, will answer.

The author supposes an institution established for electrochemistry similar to the Concilium, and discusses what it will do. In some center, an office is established which works through all the technical and scientific literature of the world. In electrochemical journals, as well as in such which an electrochemist would never consult, valuable observations are found and recorded. In advance, a list of all the topics in regard to which information may be asked, is prepared, and the cards find their way to the appropriate heading, or headings—for one must consider all the applications and relations of a new fact. If there is a heading to receive references on injuries to street mains by stray electric currents, one would be astounded at the place in which valuable notes on this theme have been published. The references supplied by such an institution would be more complete than any individual effort could secure. The card index should be a printed index, so that a letter to the office calling for information on the topic mentioned, as an example, could be at once answered by sending that collection of cards. In this, the central bureau would serve as a bureau of information; but it is evident that for financial support it would depend largely upon libraries, institutions and, in a measure, industrial undertakings becoming subscribers to the whole bibliography or a considerable portion of it.

When the central office attempts to answer such a specific question as above cited, it is evident that the applicant has little interest to know by what technical method the references are picked out for him. But the purchaser of any considerable part of the index will want to know how to arrange his cards, so that he, too, can put his hand on any question that concerns him. This can be done, if a technical device can be found which will permit each subscriber to duplicate the arrangement of the cards found in the central office. For this purpose symbols are printed on the cards which show exactly where the card belongs without considering the text. The simplest symbols are Arabic numerals and the most convenient way of using them is to arrange them as decimals, so that in the symbol 621.3, 62 is a sub-division of 6; 621 of 62, and 621.3 of 621.* Such a system permits endless expansion. As to the selection of numbers, it seems wisest to keep in touch with the most widely used system of the day, namely, the so-called decimal classification of Melvil Dewey, librarian of the New York State Library at Albany. In view of the special character of the work, this system must, however, be considerably expanded. The author is undertaking this with the aid of specialists, and the whole will ultimately be published in a key or "Conspectur."

Without, however, in any sense neglecting the theoretical aspect, it is intended that the new bibliography should be practical, for the urgent uses of the practical man. For this reason patent literature will be exhaustively treated. For so young a science as electrochemistry, it ought to be eventually possible to run back the bibliography to the beginnings of the science; but at the start the current literature should receive first attention.

Of the enormous value of such an undertaking, there can be no doubt; the question is whether it is possible to carry it out. Here it will again be necessary to say a few words in regard to the Concilium Bibliographicum. This enterprise was rendered possible by the action of the zoölogical societies of the world and by private generosity. The founder, Dr. Haviland Field, made at the start considerable financial sacrifices for the work and devoted several years to it without receiving any compensation.

At present the finances of the Concilium are such that with strict economy the staff can be paid fair salaries and the deficit is merely that covered by the annual subsidy of $1,500. The prospects are good for further improvement. Much of the expense of the Concilium consists in the maintenance of the general plant, including, as it does, a specially equipped printing office. Work done in connection with the Concilium would not only profit by nine years' experience, but would also receive the equivalent of a considerable subsidy in being able to use in part the general plant. The founding of a section of electrochemistry, in connection with the Concilium, is in accordance with the general policy of the institution. Indeed, arrangements have been made for the advance of certain funds towards the first preliminaries of such a section. These circumstances seem to decide the location of the new bureau in Zurich; but there are other reasons for such a decision. Labor is much cheaper than in America, the library facilities are excellent and are being constantly improved. Moreover, when one considers the prime function of such a bibliography, viz., that of bringing to the notice of fellow-workers matter that would have been otherwise overlooked, it is evident that to aid Americans, the best possible location is the center of Europe. What work is liable to be overlooked in America? Surely not that published in the *American Chemical Journal*, the Electrochemical Industry, the *Electrical World*. No, the great need is completeness of reference to work being done in less accessible places—in some hidden corner of Germany, in Russia, perchance. In this appears then the great value of such an American outpost—right in the very heart of Europe—in the little active country of Switzerland with its three national languages.

The experience of the Concilium teaches that such an undertaking ought to succeed. But all depends upon the support that members of the electrochemical fraternity can muster. The author has, therefore, taken the liberty of making a direct personal appeal to the members of the American Electrochemical Society. It would also be very desirable if they would urge the matter on friends, not members of the society, and above all would try to secure promises of probable subscriptions to the *whole* collection of cards on

* In the scheme, 6 means Applied Science; 62, Engineering; 621, Mechanical Engineering, and 621.3, Electrical Engineering.

the part of libraries and industrial enterprises. A provisional schedule of prices has been prepared which represents the maximum, it is quite three times the rate which the Concilium has introduced for its other branches. The latter low rates will be approximated, when the number of subscribers is sufficient.

The author enumerates briefly, as examples, some of the topics that might be chosen for subscription:

Complete subject cards.
Complete author cards.
Cards geographically subdivided.
Complete pure science cards.
Complete applied science cards.
The complete patent cards.
Patent cards of special countries.
Electrochemical theories and dissociation.
Mass action.
Polarization.
Electrolysis of mineral salts—pure or applied science cards.
Electrolysis of organic compounds—pure or applied science cards.
Primary cells.
Accumulators.
Electrometallurgy.
Electro-radiant energy.
Apparatus—experimental or industrial.
Plans and reports of plants.
Electro-therapeutics.
New books.

The address of Mr. Voege is Concilium Bibliographicum, Zurich-Neumuenster, Eidmattstr, 38, Switzerland.

GERMAN BUNSEN SOCIETY.

Report of the Ninth General Meeting in Bonn.

By H. Danneel, Ph. D.

(*Continued from page 277 of July issue.*)

Lead Tin Alloys.

A paper on this subject was presented by Dr. O. Sackur. The solubility of lead-tin alloys in acids is of great technical and hygienic importance. In order to study the same the author tried to determine the solution tension of these two metals by shaking one metal with a solution of a salt of the other one and determining the amount of precipitate. Preliminary experiments showed that Pb is precipitated by tin from a lead acetate solution, and that Sn is precipitated by Pb from a $SnCl_2$ solution. Other results are obtained with other solutions on account of the formation of complex ions. From a neutral lead acetate solution there is no precipitation of Pb by Sn, while precipitation takes place in the presence of acetic acid, the precipitation being the quicker the more acid is present. While under otherwise equal conditions the precipitation required two hours in a normal acetate acid solution, only one-fourth was precipitated after ninety hours in one-fourth normal acetate acid.

Tin goes into solution as stannous salt, and in time white stannous hydroxide or brown stannous oxide is formed by hydrolysis. While Pb is precipitated nearly completely by Sn in acetic acid solution, the reverse is the case in nitric acid solution, since Sn is quantitatively precipitated by Pb from slightly acidulated stannous nitrate. These facts can be explained only if one of the two metals in solution is strongly complex.

On the well justified supposition that lead and tin are very little complex in nitrate solution, lead must have the higher solution tension, since it precipitates Sn nearly completely from the nitrate solution. On the other hand, we must assume that in acetic acid solution Sn is nearly completely present in the complex form.

Experiments were made with chloride solutions containing free hydrochloric acid of different concentration, with solid lead chloride in excess. Since there are five phases, viz., solid Pb, Sn, $PbCl_2$, solution and vapor, and since the number of the independent constituents is also five, viz., Pb, Sn, $PbCl_2$, HCl and H_2O, the system has two degrees of freedom, viz., temperature and concentration of free HCl. These two quantities determine the solubility of lead chloride and the latter determines the concentration of equilibrium, provided there is no formation of an alloy; but this is improbable since the same equilibrium may be reached from both sides. The experiments were made at 18° and 25° C.. It was found that after equilibrium is reached, the concentration of $SnCl_2$, and that of $PbCl_2$ (within certain limits of acid concentration) are proportional to each other, the law being

$$C_{SnCl_2} = a\,C_{PbCl_2} + b.$$

A similar equation may be derived from Nernst's formula and the two dissociation equations of each metal. The author gave the results of some experiments made to find the numerical values of the constants in the equations. He then discussed the question whether the solution tension of both metals is changed, if they are present in form of an alloy or a compound. From experiment made for this purpose, he concludes that lead in solution containing more than 11 per cent Pb, has the same solution tension as pure lead, while in alloys containing a smaller percentage of lead the solution tension of Pb decreases. In general, lead and tin do not form chemical compounds, but solid solutions (with limited solubility).

The author finally described experiments in which he measured the speed of solution of the metals and alloys in various acids. Although both metals are less noble than hydrogen, the high over-voltage on the same should not allow solution with development of hydrogen, and solution should take place rather in form of an oxidation process. Pure tin is nearly insoluble in dilute acetic acid in presence of air, while pure lead dissolves easily. This difference is undoubtedly due to a difference of the speed of oxidation, since the energy of oxidation is about the same for both metals. The speed of solution of pure lead is independent of the concentration of the acid, but increases considerably with the speed of the air current which is passed through the solution.

Since stirring is of great importance, it follows that the speed of the chemical reaction is high compared with that of the diffusion. What is really measured is not the speed of solution proper, but the speed of diffusion of oxygen. In fact, stirring with a current of pure oxygen produces solution five times quicker than a current of air.

Electrometallurgy of Iron.

A paper on the Ruthenburg process was presented by Dr. Hans Goldschmidt, of Essen. The author described the principle of the process and the construction of the furnace (see Electrochemical Industry, vol. I., pages 202, 482) and gave a thermochemical calculation in which he finds (under certain suppositions) that 329 kw.-hours are required for melting 1 ton of Fe_3O_4; the figure given by Ruthenberg from measurements is 250 kw.-hours.

The report will be concluded in our next issue.

Electricity and Matter.—Sir Oliver Lodge contributes to *Harper's Magazine* for August a very interesting popular article. "Electricity is not a form of energy any more than water is a form of energy. * * * Electricity cannot be manufactured, as heat can; it can only be moved from place to place, like water; and its energy must be in the form of motion or of strain. * * * What electricity itself is we do not know, but it may, perhaps, be a form or aspect of matter. So have taught for thirty years the disciples of Clerk-Maxwell. Now we can go one step farther and say matter is composed of electricity, and of nothing else." The author then gives a summary of the electronic theory and its relation to the constitution of matter.

SOLUBILITY OF GOLD IN CERTAIN OXIDIZING AGENTS.

A paper presented by Dr. Victor Lenher, of the University of Wisconsin, at the St. Louis meeting of the American Chemical Society, is quite interesting, since it shows that under certain conditions, gold is soluble in a much larger number of solutions than is generally supposed. The dissolving action of anodic oxygen in certain solutions should be of special interest to our readers.

The inactive character of gold is so pronounced that towards many of the reagents the element is quite indifferent. In fact, almost the only solvents in general use for dissolving the metal are chlorine, bromine or a solution of alkaline cyanide in presence of atmospheric oxygen. Chlorine and bromine attack the metal readily, while iodine only dissolves the metal when it is fresnly liberated, or under other very favorable circumstances. The metallic perchlorides, perbromides and periodides, according to Nickles,[1] dissolve gold, the lower halides of the metal being formed along with gold chloride. Hot selenic acid readily dissolves gold. Iodic acid has slight action on the metal, while, according to Prat,[2] a mixture of iodic and sulphuric acids dissolves gold when heated to 300° C. Gold is readily soluble in a mixture of hot sulphuric and periodic acids, and also slightly soluble in the alkaline sulphides and thiosulphates.[3]

Dr. Lenher then points out that there is another class of substances—substances which evolve oxygen when treated with acids—whose action on the gold has received very little attention. He had formerly found that gold is readily attacked by pure hot selenic acid with the formation of auric selenate. In following the same line of work with telluric acid, which in many respects is closely analogous to selenic acid, the obstacle is met that the telluric acid is a solid. This difficulty can be obviated by first dissolving the crystalline telluric acid in sulphuric or phosphoric acid. Such a solution of telluric acid, when heated, dissolves metallic gold.

With the fact at hand that at the same temperature at which selenic acid or a solution of telluric acid attacks gold, the acids themselves are broken down into the dioxides and oxygen, it appeared probable that the solvent action in these cases was due to the production of oxygen in the reaction. Dr. Lenher argued that, should this view be correct, gold should be soluble in acids when an oxidizing agent is present. The action of a large number of substances, such as oxides of various types, sulphates, etc., was tried on gold in presence of sulphuric, phosphoric and arsenic acids, and only such substances as give oxygen in presence of the acids will act on gold. In most cases, the only precautions necessary in order to demonstrate the solvent action is to have the acids in a high degree of concentration.

All of the substances that have been used in the following experiments of Dr. Lenher were carefully tested for the halogens and only such substances were used as were halogen-free.

The first substance examined was manganese dioxide, as it is well-known that manganese dioxide gives oxygen when heated with sulphuric acid. A mixture of manganese dioxide and sulphuric acid, when heated for a few minutes with gold, causes the metal to go into solution. On diluting the solution and testing with oxalic acid or ferrous sulphate, all of the gold is precipitated. In working with manganese dioxide and sulphuric acid, practically the only precaution necessary is to have the acid concentrated. Solution of gold in presence of manganese dioxide and sulphuric acid takes place readily when the mixture is hot, but the reaction also takes place in the cold. A mixture of manganese dioxide and sulphuric acid, when allowed to remain in contact with gold leaf for twelve hours at 0° C., will dissolve sufficient gold to give an appreciable precipitation, when the mixture is diluted and treated with ferrous sulphate. It is thus seen that while heat accelerates the reaction, solution nevertheless takes place at low temperatures.

The higher oxides of manganese act in an entirely similar manner. The substances actually worked with were manganese dioxide (*a*) native, (*b*) from the ignition of manganese nitrate, (*c*) by the action of bromine on manganese acetate: Manganese sesquioxide (Mn_2O_3), manganese protosesquioxide (Mn_3O_4), and potassium permanganate. The solvent action takes place in a similar manner when phosphoric or arsenic acid is substituted for sulphuric, but the action is greatly moderated.

In 1872 Allen[4] showed that when solid potassium permanganate and sulphuric acid are heated for a few minutes with precipitated gold the solution becomes nearly clear, and on diluting and testing with oxalic acid or ferrous sulphate the solution was found to contain abundance of gold. This experiment was repeated by Dr. Lenher, using sulphuric acid as described by Allen, and also by substituting phosphoric for the sulphuric acid. In all cases solution takes place and the gold can be readily detected by ferrous sulphate.

Lead dioxide, lead sesquioxide and red lead, when used with sulphuric acid, cause gold to enter into solution. The action takes place more readily in the warm than in the cold, though at the ordinary temperatures solution does actually take place, gold being found in the solution after several hours' contact.

With the higher oxides of lead, phosphoric acid can be substituted for the sulphuric acid, solution being affected. With chromium trioxide, chromium tetroxide and nickelic oxide, solution of gold is effected in presence of sulphuric or phosphoric acids, the reaction taking place, though moderated, in the cold.

When nitric acid is subjected to heat, more or less decomposition is effected, part of the acid breaking down into nitrogen dioxide and oxygen. This reaction can be used in a highly satisfactory manner to demonstrate the solubility of gold in sulphuric acid in presence of an oxidizing agent. This reaction was first noted by Reynolds,[5] and later by Spiller.[6] The results which these chemists obtained were confirmed by Dr. Lenher, and show that when a mixture of hot nitric and sulphuric acids comes in contact with gold the metal enters into solution and, at the same time, a lower oxide of nitrogen is formed by the reduction of the nitric acid and this oxide remains in the solution.

That a lower oxide of nitrogen is present in the solution after the gold has dissolved can be demonstrated in a very pretty manner, as Spiller has shown, by adding the solution to water when the metal is thrown out as a purple precipitate. Allen[7] later showed that this precipitation by water from nitric-sulphuric acid solution is due to the presence of a lower oxide of nitrogen, probably nitrous acid, since when the water used for dilution contains potassium permanganate no precipitation takes place. Also ammonium sulphate destroys the nitrous acid and, after boiling with ammonium sulphate, no precipitation takes place, while when fuming nitric acid is added to any of the liquids, the gold is thrown down, purple in color. While Reynolds, Spiller, and Allen have studied the reaction of a mixture of hot nitric and sulphuric acids on gold, the influence of temperature on the reactions seems to have escaped their attention, and also that certain other acids, as phosphoric acid, can be substituted for the sulphuric acid with practically as great solvent action taking place.

While a mixture of nitric acid with either sulphuric acid or phosphoric acid readily acts on gold when warm, solution actually takes place, though more slowly, even at zero.

The action of oxygen gas on gold leaf, suspended in hot

[1] Ann. Chim. Phys. (4), X, 318.
[2] Compt. Rend., 50, 840.
[3] Stedefelt: "Lixiviation of Silver Ores," pp. 15, 38.
[4] Chem. News, 25, 85.
[5] Ibid., 10, 48, 167, 277.
[6] Ibid., 10, 173.
[7] Chem. News, 25, 85.

sulphuric acid, was also tried, but neither oxygen nor ozone would cause any of the metal to pass into solution.

The anode oxygen, obtained in electrolysis, was next studied as to its action on gold. Bunsen noticed, when using for the electro decomposition of water an apparatus in which the platinum electrodes were connected with the terminals by means of gold solder, that on electrolyzing in presence of dilute sulphuric acid there is a film of oxide formed on the gold. Later it was shown by Spiller that when a plate of metallic gold is made the anode and a piece of platinum foil or gauze used as the cathode in an electrolyte of sulphuric acid or a mixture of nitric and sulphuric acids, the gold anode dissolves and the metal was deposited on the cathode, the source of the current used being a few Grove cells.

This work, which has been repeatedly verified, demonstrates that in presence of strong sulphuric acid, solution of gold can be effected readily by means of anode oxygen, the action proceeding rapidly when the acid is hot. On the other hand, when the acid is dilute the oxide of gold formed does not pass through the solution and deposit on the cathode as metal, but remains as an incrustation on the gold anode. Here again, a similar series of results is obtained when phosphoric acid replaces the sulphuric. When solutions of the acid sulphates of potassium or sodium are used as electrolytes, the action goes on exactly as above indicated. If the solution contains sufficient acid, gold passes through the electrolyte, while if the solution is dilute or contains only a little free acid, the oxide remains as a film on the anode.

In the case of an alkaline electrolyte, such as a solution of sodium or potassium hydroxide, it is possible for some of the gold to pass through the solution, probably from the formation of aurate of the alkali. Such is actually the case, although in alkaline solution a large amount of oxide remians as an incrustation on the gold anode employed. When neutral salt solutions are employed as electrolytes, such as the nitrates or sulphates of potassium or sodium, very little, if any, of the gold, can pass through the elctrolyte, and as a result the anode is converted into the oxide Au_2O_3. Here we have the last step in the series of experiments, viz., obtaining the gold oxide in pure condition and retaining it as such.

In the above series of experiments the current used was 0.3 to 0.5 ampere at a pressure of 5 volts, the anode being a sheet of gold, and the cathode a 20-gram platinum crucible. In such experiments where gold was deposited on the crucible, the quickest method found for removing the metallic deposit, which frequently appeared as a hard plating, was found to be the hot mixture of nitric and sulphuric acids, as indicated above. This method was found to be vastly superior to that of the use of a cyanide solution, such as was at first used.

It thus appears that gold is not only attacked by the halogens, but is also readily attacked in a large number of reactions in which oxygen is produced, these latter reactions taking place readily in the warm solutions, but slowly even at as low a temperature as zero. Furthermore, it appears that it is necessary for the oxygen to be produced in the mixture and that ordinary oxygen gas, when conducted into sulphuric acid in which gold leaf is suspended, will not cause the gold to dissolve.

THE EDISON-JUNGNER CASE.

During the last weeks charges preferred by Mr. Thomas A. Edison against two examiners in the United States Patent Office, with respect to patent 738,110, granted on September 1, 1903, to Ernest W. Jungner (Electrochemical Industry, October, 1903, page 508), have attracted considerable attention. Mr. Edison preferred three charges. "First, that the examiners in question allowed the Jungner patent to issue when they knew or should have known that such issue was fraudulent. Second, that the examiners allowed the said patent to issue containing claims which they knew were unpatentable, and which, in fact, they had declared to be unpatentable, and which Jungner himself had admitted were unpatentable. Third, the examiners granted the said patent for an inoperative invention, which fact had been previously brought directly to their attention and acknowledged by them."

The charges made against the two examiners were referred by the Secretary of the Interior to the Commissioners of Patents, who decided that the charges were without merit and therefore recommended that no hearing be given. Mr. Edison's counsel appealed to President Roosevelt, who decided that a full hearing be given to Mr. Edison. The Commissioner of Patents referred the matter to his assistant, Mr. Moore, before whom the argument was made.

Copyright, 1904, by N. Lazarnick.

THOMAS A. EDISON.

The main point made was that Jungner bases his case on an application for a patent filed in the spring of 1899; that he tried two years afterwards by amendment to include certain chemical and mechanical features; that this was not permitted by the Patent Office on the ground that the amendments embodied new matter; that in June, 1902, Jungner filed an application for a patent which was represented as being a division of his original application of 1899; but this divisional application contained the same features of "new matter" which he had been unable to embody in his original patent by way of amendment. In his report on the hearing, addressed to the Secretary of the Interior, the Assistant Commissioner says that "the disclosure in the Jungner patent is a different invention from that originally disclosed by him in his parent application, and therefore there is no basis in the original disclosure for the disclosure of his patent, and that therefore, the examiners erred in allowing the Jungner patent as a division of the earlier application, as the patent is not in fact a division, for the reason that it not only contains new descriptive matter relating to its mechanical structure, but the invention disclosed is so changed as to be, in fact, another invention from those originally disclosed in the early application and that the patent therefore as to this new matter is effective only as to its new filing date." Thus, the two examiners were found to have erred, though there was absolutely no evidence of malfeasance or intentional wrong-doing. They were relieved from their present assignment and transferred to another examining division of the Patent Office.

E. W. JUNGNER AND M. U. SCHOOP.

* * * *

The adjoining portrait of Mr. T. A. Edison, with the incandescent lamp was recently taken in connection with the twenty-fifth anniversary of his invention of the lamp. For the por-

trait of Dr. E. W. Jungner and Mr. M. U. Schoop we are obliged to the latter gentleman. The picture was recently taken in Norrkoeping, Sweden, where the Jungner-Accumulator Aktiebolaget has a plant. Mr. Schoop is the chief engineer of the German storage battery concern which has bought Dr. Jungner's German patents, and is the author of the able paper on the oxygen-lift cell which is concluded on another page of this issue.

* * * *

According to a note published in the *Elektrotechnische Zeitschrift* of July 21, the Jungner Co. has installed three automobiles for passenger traffic between Norrkoeping and Kneippbaden in Sweden. The present Jungner accumulator is said to differ little from the Edison cell. The active masses of nickel and iron hydroxides, mixed with graphite, are placed in pockets under strong pressure. "Jungner makes the units considerably greater than Edison, eight unit-pockets being combined in one electrode. The thickness of the plate is 3.5 mm. for the positive electrode and 2.5 mm. for the negative electrode. The distance between the plates is 2 mm. Chemically pure 20 per cent potassium hydroxide solution is used as electrolyte." An article by Schoop, giving historical notes on Jungner's work, was abstracted on page 289 of our July issue.

It is stated that Jungner is now renewing his former experiments with the silver-cadmium battery with which he is said to be able to get fifty or more watt-hours per kg. of total cell.

SYNOPSIS OF ARTICLES IN OTHER JOURNALS

A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.

INDUSTRIAL ELECTROCHEMISTRY.

Electrolytic Treatment of Zinc Sulphides.—In our August issue, 1903, page 412, we described the Swinburne-Ashcroft process for treating complex sulphide ores; the last step of this process is the electrolysis of fused zinc chloride. In the *Engineering and Mining Journal*, June 2, C. A. BURLEIGH gives some interesting results obtained by electrolysis of aqueous solutions. Various ores were treated by an alkaline solution which was electrolyzed, and the lead plated out completely, after which, in another set of cells, the most of the zinc was plated out and the solution returned to fresh ore, where it was again enriched by lead and zinc dissolved from the fresh ore; care being taken that a large enough amount of solution was used so that all the zinc and lead in the ore could go into the solution without saturating it. The voltage used in the lead cells varied from 1.5 volts to 1.7 or 1.8 volts per cell, depending upon the degree of concentration of the solution, also upon the percentage of lead in solution and number of amperes per square foot of cathode surface. Chiefly, although some other factors may, and frequently do, cause some slight variations, the first cells always show the lowest voltage. A fair general average of the voltage in the lead cells would be 1.6 volts per cell, using 130 to 140 ampere-hours to deposit a pound of lead. In the zinc cells the voltage may be made to vary within very wide limits; good work may be done from 2.25 to 5.6 or even 7 volts per cell, using a varying amperage of from 8 to even 200 amperes per square foot of cathode surface. With properly constructed cathodes 400 to 425 ampere-hours sufficed to produce a pound of zinc. As 375 ampere-hours are what theory calls for, the commercial ampere-hour efficiency falls between 88 to 93 per cent. While variations in the strength of solution, per cent of zinc carried and position of the cell in the series do cause differences of voltage, the number of amperes used per square foot of cathode surface is the great controlling factor; any increase in the number of amperes used increases the voltage. Equally good work can be obtained by using 2.2 volts up to 6 volts per cell, so far as the quality of the metal is concerned; it is deposited, hard, smooth and dense and of high tensile strength at any voltage within these limits. It is purely a commercial question whether to use 2.25 volts and 8 or 10 amperes per square foot, or 3 to 3.5 volts and about 30 amperes per square foot, or even a higher amperage per square foot of cathode surface. A higher efficiency requires a relatively larger plant per pound of zinc produced than a lower. Sometimes it is good policy to force the cells to do double the work and produce double the number of pounds of zinc per day, even if it does cost a little more current for each pound of zinc produced. As equally good results have been obtained from ores varying from 12 to 59 per cent of zinc and 4 to 20 per cent lead, the value of the metals left in the tailings will frequently control the easily regulated efficiency of the zinc plant. With high values in, for example, gold, silver and copper, and with plenty of smelter capacity and also of ore, it might be true economy to use a high voltage and get off the greatest tonnage possible. After several continuous runs, some five or six months long, the solution, although several different ores were treated, some containing arsenic and manganese, was not vitiated.

Ferro-Silicon.—The June issue of *L'Industrie Electrochimique* contains an article on the manufacture of ferro-silicon, with references to a paper by Keller on this subject. The fact which has brought the electric furnace to the front in this line of work is the ease of producing a ferro-silicon, containing a high content of silicon, from 25 to 80 per cent. (The advantages, resulting from this fact, were pointed out in an article in our March issue, 1904, page 122.) The electric furnace manufacture of ferro-silicon can be economically carried on only in large plants with powerful electric furnaces. The starting materials should be quartz, scrap iron and coke. Quartz is preferable to sand, since the latter is able to clog the furnace. Iron and steel scrap is preferable to iron ore, since, with pure quartz, the operation is "slagless." The purity of the ferro-silicon produced depends on the care taken in the operation.

Electrometallurgy of Iron and Steel.—In a paper read before the Canadian Society of Civil Engineers and abstracted in the *London Elec. Rev.*, of June 24, A. STANSFIELD discusses the possibilities of the various electric furnace processes for the preparation or refining of iron and steel. Relying on a large number of figures, he holds that electrical energy can be bought in Canada on a large scale at the price of about 0.15 cent per hp.-hour or 0.20 cent per kw.-hour. If, then, the reduction of one metric ton of pig iron from ore requires 2500 kw.-hours, the cost of energy comes to $5.00 Against this may be set the price of fuel saved by using electric heat. This is about 0.6 ton of coke which, at $2.50 per ton, is equal to $1.50 per ton of iron. Thus, electric smelting of such ores as are capable of treatment in the blast furnace cannot compete with the latter, even where very cheap water power is available, unless the price of coke is $8.00 per ton. There are, however, certain ores, such as iron sands and titaniferous ores which can only be treated with difficulty in the blast furnace; for these the absence of the blast and the higher attainable temperature may render the electric furnace more useful. Moreover, refractory ores exist which can only be treated at all if they prove suitable for reduction in the electric furnace. Probably the greatest field of usefulness of the electric furnace, however, will be found in the production of crucible steel. He thinks that the electric manufacture of crucible steel is technically and financially possible in Canada; the

energy might be developed from water power or by gas engines fed by blast furnace gas.

In *Stahl und Eisen*, June 15 and July 1, B. NEUMANN begins a long critical review of the various processes which have been proposed for the application of the electric furnace to the iron and steel industry. He begins with the process of Ruthenburg and then passes over to a discussion of the various processes in which furnaces with carbon electrodes are used. The following furnaces are described: Siemens, De Laval, Stassano, Conley, Heroult, Keller, Harmet. He then passes over to the description of processes in which no carbon electrodes are used and describes the furnaces of Kjellin, Gin and Girod. The article is to be continued.

Electrolytic Iron.—The great interest which has been aroused by Burgess and Hambuechen's recent paper on the electrolytic refining of iron (ELECTROCHEMICAL INDUSTRY, May 1904, page 184) is shown by two notes published in foreign journals. W. W. H. GEE states in the London *Electrician*, June 24, that he made some experiments on the electrodeposition of iron fifteen years ago, wishing to deposit rings of pure iron for the purpose of determining the permeability by the method of Rowland. The solution with which he obtained his best results was the same which Burgess and Hambuechen advise—*i. e.*, one containing sulphates of iron and ammonium. He obtained fine deposits of iron on flat rings of copper, but was unable to get any considerable thickness. One difficulty which he encountered, was the oxidation of the solution and the electrodes; to obviate this he fitted up an arrangement for carrying on the electrolysis in an atmosphere of hydrogen.

In the *Elektrochemische Zeit.*, July, A. NEUBURGER writes that in 1890 he and N. von Klobukow made experiments on the deposition and separation of iron by electrolysis for analytical purposes. They found that under certain conditions, iron can be deposited in quantitative amounts up to one gram; with greater amounts the deposition is no longer quantitative, but if the conditions of analysis are maintained with some modifications, the iron can be deposited in large quantities and in very good form. They thus produced a half sphere and a total sphere with a wall of one cm. thickness. The purity of their iron was 99.9 per cent. They did not observe any contents of hydrogen in the iron. They found that their electrolytic iron would not rust, even though they endeavored to make it rust. Their method was as follows: They used a solution of crystalized ferrous sulphate in water, carefully neutralized with ammonia; in case of any excess of ammonia, oxalic acid was added. A considerable amount of ammonium oxalate was added to the solution. The current density was one ampere per square decimeter, the voltage being in the average about 3.5 volts. During electrolysis, brown iron carbonate was some times precipitated, which could be dissolved by an addition of oxalic acid. The precipitate adhered very firmly and was difficult to remove in all cases.

Refining of Silver.—An article on the electrometallurgy of silver refining is published in *L'Industrie Electrochimique*, June. If a dilute silver nitrate solution is electrolyzed with a silver plate containing gold as anode, silver dissolves and is deposited on the cathode, while the gold remains in the anode slime. If the anode sludge is boiled with nitric acid the small quantities of silver still contained in it are removed and gold of a purity of 0.999 may be obtained. Some details are given on the process of the St. Louis Smelting and Refining Co., and on some other plants.

Electrolyzer for Copper Refining.—D. TOMMASI describes a somewhat peculiar apparatus for copper refining in *L'Electricien*, June 25. A rectangular tank contains a solution of acidulated copper sulphate to which are added certain "dopes" to cause a compact deposit of the copper and to reduce the resistance of the electrolyte. Between two copper anodes the cathode is placed, consisting of a disc formed of a number of metallic segments on which the copper is deposited, while the disc is revolved at a speed of 80 to 100 revolutions per minute, with a current density of 1 to 2 amperes per square decimeter. When the copper deposit is sufficiently thick, the segments are removed, without interrupting the operation.

Bismuth.—In *L'Industrie Electrochimique*, June, H. BECKER gives a review of the electrometallury of bismuth. No electrolytic or electrothermic processes have been proposed for the extraction of bismuth from its minerals and the prospects of the application for such methods are poor, since bismuth minerals are found in districts where they must be worked by a process of little complication and without expensive installations. For the winning of bismuth from raw lead, Borchers has described a process which is discussed in some detail. It consists essentially in the electrolysis of fused alkaline chlorides in contact with raw lead as anode. Lead dissolves and is deposited on the cathode, while bismuth and silver remain undissolved. It does not seem that his process has ever been employed on an industrial scale.

Electrolytic Oxygen and Hydrogen.—The problem of producing oxygen and hydrogen by electrolysis of an acid or caustic solution resolves itself into preventing the oxygen and hydrogen gases which are generated at the anode and cathode, respectively, from mixing. In the Hazard-Flamand process, which is described in the *Electrochem. and Met.*, June, from a report of Prof. Dalby, the anode and cathode are kept separated from each other by means of insulating partitions which of course do not fill the whole cross-section of the cell; their peculiar mechanical construction is the novel feature of the apparatus. The corrugated inside walls of the box A, and of

FIG. 1.

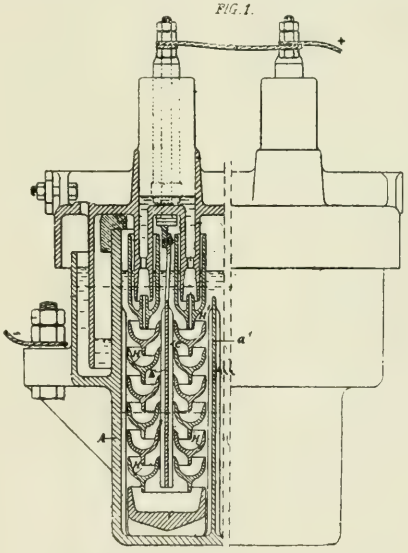


FIG. 1.—ELECTROLYTIC PRODUCTION OF HYDROGEN AND OXYGEN.

the transverse partitions a^1 form the cathode, while in the center of each chamber, thus formed, the anode E is placed. The insulating partitions which keep the anodic oxygen separated from the cathodic hydrogen are provided in the form of gutters H, of Y cross-section, made of ebonite, porcelain or glass. The construction is shown in Fig. 1, and it will be seen that the electrolyte has a clear passage from the anode to the cathode, while the construction of the gutters H is stated to prevent the gases from mixing so effectively that the oxygen is 99 per cent pure. The electrolyte used is a solution of 15 per cent caustic soda and distilled water. If 2.1 volts are ap-

plied at the voltameter terminals the yield of oxygen per kw.-hour is 141.7 grams, giving a watt-hour efficiency of 66.5 per cent. For 2.8 volts the yield of oxygen is 106.3 grams per kw.-hour, the watt-hour efficiency being 50 per cent. A plant using this process is situated near Paris.

Theoretical and Experimental.

Electrolysis of Acid Sodium and Calcium Sulphites.—In the *Zeit. f. Elektrochemie,* July 8, A. R. Frank describes some experiments in which he electrolyzed acid sodium and calcium sulphites in the following apparatus: A large porous cup contained the platinum cathode and was filled with the sulphite solutions. It was itself placed in a glass vessel containing sodium chloride or sodium hydroxide or sulphuric acid solutions with corresponding anodes. With acid sodium sulphite, in the cathode compartment it was easy to get $Na_2S_2O_4$, but after some time this began to become decomposed. Nevertheless a good ampere-hour efficiency can be obtained for some time if special precautions are taken. It is especially important to use neutral solutions. He succeeded in obtaining solutions containing 30 to 40 grams $Na_2S_2O_4$ per liter, when starting from solutions that contain 5 per cent SO_2. With $CaH_2S_2O_6$ in the cathodic compartment (containing originally 40 to 60 grams SO_2 per liter) he could produce for some time CaS_2O_4 solution with an ampere-hour efficiency of 60 to 70 per cent.

Copper Anodes.—If a copper plate is used as anode in an electrolyte which allows the formation of a soluble copper salt, the supposition generally held is that the copper goes into solution with formation of this salt. Under certain conditions, however, a peculiar phenomenon is observed. Two copper wires are suspended in sulphuric acid of maximum conductivity; they may be 1 mm. thick and suspended into the electrolyte 10 mm. deep; if now an e. m. f. of 20 volts is applied at the two wires, the anode wire is pulverized, giving off dense clouds of a dark dust which remains suspended in the electrolyte for a long while, the dust consisting of metallic copper; simultaneously cupric sulphate is formed in the electrolyte. If the e. m. f. of 20 volts is not applied immediately, but the voltage at the two wires is raised gradually, it will be observed that the pulverization of the copper anode is preceded by a condition which is quite analogous to the electrolytic valve action of the aluminium anode. When the e. m. f. is then gradually raised, the pulverization of the anode takes place as soon as the condition of the anode which counteracts the passage of the current is overcome. Starting from these phenomena, F. Fischer has studied in detail what takes place on the copper anode, an account of his results being given in the *Zeit. f. Elektrochemie,* June 24. He remarks that the formation of copper dust on copper anodes in sulphuric acid is nothing essentially new; it is, for instance, observed in copper voltameters in which, with the usual current density, the anode is not dissolved completely to $CuSO_4$, but there is always simultaneously a precipitation of dark dust on the anode which was before absolutely bright. This dust is now known to be copper which is produced from primarily formed cuprous sulphate according to the ionic reaction $2Cu^{\cdot} \rightleftarrows Cu + Cu^{\cdot\cdot}$. The main results of Fischer's investigations are as follows. When the current density is gradually being increased at a copper anode in sulphuric acid, a transition resistance is produced caused by the deposition of a solid salt, as soon as the speed of formation of the salt is greater than the speed of its solution. If the current is maintained constant, the current density then increases, and with it the e. m. f. at the terminals. As long as the anode does not get hot, oxygen is produced together with cupric sulphate. When the temperature of the anode rises, the formation of oxygen stops, and, besides cupric sulphate, increasing quantities of cuprous sulphate are produced. If the temperature in the pores rises up to the boiling point of the electrolyte, the anode is pulverized with a singing noise, clouds of very fine copper dust being formed. What happens is that the steam blows the mixture of cupric and cuprous sulphate (formed at the copper anode) into the cold electrolyte, where the cuprous sulphate (which had been formed at high temperature) is decomposed into copper dust and cupric sulphate. The ratio of the quantity of copper dust to the simultaneously formed quantity of cupric sulphate increases with the concentration of the sulphuric acid, that is, with the temperature in the pores causing pulverization (which is equal to the boiling point). Up to 50 per cent of anodic copper may be dissolved primarily as cuprous sulphate. A result of the formation of copper dust is the fact that at a copper anode at high-current density, chromic acid and the like are reduced.

Stirring During Electrolysis.—For various purposes of electrolysis—in industrial operation as well as for analytical purposes—the great importance of strong agitation of the electrolyte has long been recognized, but its importance has been recently emphasized in some special cases and it seems that some people have been surprised at the effect produced by stirring. In an article published in *Zeit. f. Elektrochemie,* July 8, H. Sand points out that there is nothing mysterious in the effect of stirring. It seems not doubtful that the current density which is permissible for electrolyzing a certain solution depends upon nothing else but the speed with which the layer of the electrolyte next to the electrode is replaced by fresh solution. For depositing metal, the cathode potential is independent of the current density, and the condition of the metallic deposit depends to a very small degree only on the current density—as long as the layer of electrolyte next the cathode remains the same. The great differences which are observed in practice with various current densities, result from nothing but local concentration changes. If there was no diffusion, continuous electrolysis would be impossible, since otherwise the concentration of the metal ions near the cathode would instantaneously decrease to zero. Diffusion must also be supplemented by convection currents in order to destroy concentration differences. He gives a formula for the time in which the concentration at the electrode would decrease to a given fraction if there was no convection or artificial stirring. He makes a few remarks on plating on articles which have non-uniform surfaces, containing holes, etc. The conditions which are favorable to high-speed electrolysis, are unfavorable to good "straying" of the lines of current (as required for plating the inside of holes, etc.), but this does not prevent the production of coherent metallic deposits during high-speed electrolysis.

Very Small Ionic Concentrations and the Atomic Theory.—The beauty of the electrolytic dissociation theory rests to a large degree on the simplicity and conciseness of its propositions, and on the relative ease with which it has been possible to work it out mathematically. It is not surprising that in working out detailed results and following up all consequences of the theory, some times discrepancies between facts and theories were found, and in other cases the theory led to results which, while not directly wrong, yet offered difficulties to the conception. Among the latter were the extremely small ionic concentrations which have some times been calculated as results of measured e. m. f.'s. and Nernst's theory of solution tension. Ostwald once found by such a method that one cc of a solution with which he worked should contain only two silver ions. If the volume of one cc was then divided into three portions, at least one of them would contain no silver ion. Ostwald tried to get out of his difficulty by pointing out that an individual silver ion which exists in solution is not necessarily an ion all the time. Any silver atom which exists in the solution in form of the complex ion $Ag(CN)_2$, can and will become a silver ion for some time, and the figure for the ionic concentration really gives the time for which a silver ion can exist as such compared with the time for which it exists as part of the complex ion. In a short but interesting paper in the *Zeit f. Elektrochemie,* July 1, F. Haber criti-

cises this view and points out that in such changes electric charges are involved, and that such a change cannot be quicker than electric changes in general. Electric impulses are propagated with the speed of light. From this figure we can arrive at a minimum time which we are justified to assume in the formation of complex ions. Haber finds that the theory here gets into difficulties which have not yet been solved. He reaches the result that the reality of the extremely small concentrations which are calculated from e. m. f's. in complex solutions, is a somewhat arbitrary assumption. On the basis of the atomic theory, it is difficult to imagine ionic concentrations smaller than the OH' concentration in one ion-normal sulphuric acid, and it seems impossible to imagine such small concentrations as have been calculated in the above example of the silver ion.

General Metallurgy and Miscellaneous.

The Behavior of Several Metals in Sea-Water has been studied by twelve-month tests, in the harbor of Kiel, by Engineer Diegel, and reported *in extenso* in *Stahl und Eisen* of May 15 and June 1, 1904. Particularly interesting for electrochemists is the behavior of different metals in contact with each other, and moistened by sea-water. Thus, for two irons containing different percentages of phosphorus, of equal surface and in contact with each other, the iron with 0.01 per cent phosphorus was always the anode, and was corroded three to six times as fast as iron with 0.09 to 1.08 per cent of phosphorus. Regarding the corrosion of nickel steel, isolated and insulated plates showed losses by corrosion corresponding to 6 milligrams per square decimeter per year for no nickel, 4 milligrams for 6 per cent nickel, and thence decreasing linearly to 1.6 milligrams for 30 per cent nickel. When two steels with different nickel contents were in contact with each other, the higher nickel alloy acted as cathode and was practically untouched during twelve months' immersion, but the lower nickel steel was corroded two to ten times as much as it was when insulated and alone. The potential difference between these steels increased as the content of nickel increased, the lower nickel alloy being the anode. As practical results of these observations are the recommendations that steel parts of boilers and ships' hulls should be made with a uniform content of phosphorus and of nickel. If a particular part of a boiler is strongly corroded, such as the tube, it will be of advantage to make it of higher phosphorus than the rest of the boiler. Where nickel steel is used in ships in contact with nickel-free steel or iron, the nickel should be kept to as low a per cent as possible, to avoid excessive corrosion of the nickel-free parts. With 6 per cent nickel steel, it is practically untouched, while the nickel-free parts in contact with it are corroded 50 per cent faster than when insulated and alone. If a certain part of a steel or iron body immersed in salt water needs particular protection or preservation, and is not very large in comparison with the whole body, it will be untouched if made of a high nickel steel—30 per cent is recommended. If the 30 per cent nickel steel is used, however, in combination with copper or bronze, it (the steel) will act as anode in this case, and be very strongly corroded.

Regenerative Gas Furnaces.—A circular of the Friedr. Siemens Company apprises us of the large field already occupied by the new form of regenerative gas furnace, which may be new to some of our readers. Since over 1000 of these furnaces are now in operation, mostly for melting small charges up to 10 tons, and have been found most economical, their use may certainly be regarded as a permanent advance in the metallurgical art.

The gas producer is united with the furnace in one structure; as in the well-known Bicheroux furnace, but the gases, passing into the rectangular melting chamber, pass in alternately at one end and the other, passing thence through regenerators into the chimney. The regenerator, which is not being heated, is used for heating the air supply which burns the gas at its entrance into the furnace. If the producer runs too hot, part of the chimney gases may be diverted into it, the carbonic acid of which is converted into carbonic oxide in the producer and thus redevelops heat in the furnace. A ten-ton steel furnace is claimed to cast only 60 per cent of the cost of an old-type Siemens furnace, the space occupied to be a trifle over half, and the fuel consumption only 300 kilos per ton of steel, as against 500 kilos in the older type of furnace. For foundry use, it is claimed that it will replace an ordinary reverberatory furnace to such good effect as to save its cost within a year.

High-Speed Tool Steels is as fascinating a subject to the scientific metallurgist as it is important to the machinist. To find a steel of such composition that, by peculiar and appropriate treatment, it will retain cutting hardness at a low-red heat, is a problem which has recently been solved in a most satisfactory manner, and which has been at once utilized industrially. In the *Revue de Metallurgie* for May, 1904, L. Guillet discusses at length the properties of tungsten steels, and in the same journal for June, 1904, is an article by Prof. H. Le Chatelier on high-speed tool steels.

Guillet comes to the conclusion, by applying Frémont's system of studying resistance to shock, that there is a critical point in the content of tungsten, viz., 5 to 7 per cent, below which these steels have the same structure as simple carbon steels, their strength and hardness increases proportionately to their tungsten content, and their fragility is sensibly unaltered; above this tungsten content they have a high tensile strength, low elastic limit, small elongation and reduction of area, and are of great fragility, but their hardness is great and increases with their carbon content. Under the microscope, when tempered, the first class shows pearlite, like ordinary steel, the second class, hardened from 850°, shows extremely fine martensite, *i. e.*, uniformly distributed carbide, with some carbide undissolved. Steels in which the tungsten is more than six times 1.6 per cent less the carbon content belong to the second class, where the tungsten is less than this, to the first class. The second class, of course, are the high-speed steels.

Prof. Le Chatelier discusses the experiments and patents of Messrs. Taylor and White, of the Bethlehem Steel Co., saying that when, in 1900, the news spread in Paris that at the annex in Vincennes an American firm was cutting off enormous turnings of iron with a tool which was red-hot at the point while cutting, every one smiled at the report, regarding it as a "Yankee bluff" until they had seen the thing with their own eyes. In his article, Le Chatelier explains very clearly how the presence of the tungsten raises abnormally the temperature at which the tempering or softening of the steel takes place, and that this temperature is also dependent on the temperature from which the tungsten steel has been hardened. The recent improvements in these steels have been to increase the tungsten up to as much as 20 per cent, chromium being usually present from 1.5 to 8 per cent, and to avoid excessive hardness or brittleness by reducing the carbon below 1 per cent, usually to 0.5 or 0.7 per cent. Prof. Le Chatelier supports this statement by seven analyses recently made by himself, all falling within these limits, but in which, according to his own statement "le molybdène n' a pas été dosé." If he had looked for and determined the molybdenum, he would have found, to his surprise, that the most recent high-speed steels contain not such quantity of molybdenum as may be ignored in an analysis, but 4, 6 and even up to 10 per cent of molybdenum, the tungsten being largely diminished. In this manner, a steel is obtained with less percentage of hardening elements, and not so apt to crack in hardening. America took the lead in high-speed tool steel, by Messrs. Taylor and White's invention, but it is keeping at the front by the judicious use of high percentages of molybdenum, a fact which Prof. Le Chatelier might have discussed had he "determined the molybdenum" in the specimens which he analyzed.

Theory of the Blast Furnace Process.—In a paper by R. Schenck, published in the *Zeit. f Elektrochemie*, June 10, the author refers to the composition of the blast furnace gases; as an average he gives the following composition:

N 54 to 66 per cent.
CO_2 7 to 19 per cent.
CO 21 to 31 per cent.
H_2 1 to 6 per cent.
Hydrocarbons 0 to 6 per cent.

The average proportion of CO to CO_2 varies between 2.44 and 1.04. The author discusses the conditions on which this ratio depends. The reaction $FeO + CO \rightleftarrows Fe + CO_2$ is reversible and is not complete, and an equilibrium is reached when the reaction of the above equation going from the left to the right hand occurs with the same speed as the reverse reaction (from the right to the left hand). Baur and Glaessner started once with FeO and CO, and in other experiments with Fe and CO_2. The analysis of the resulting mixture of gases gave exactly the same composition in both cases. This equilibrium is independent of the atmospheric pressure, but depends on the temperature as is shown in the following table:

Temperature	Contents in Gas Mixture.	
Degrees Centigrade.	Per cent CO.	Per cent CO_2.
550	64	36
680	59	41
750	61	39
900	71.5	28.5

The minimum content of CO is therefore obtained at a temperature of 680° C., this corresponding to the ratio CO to $CO_2 = 1.44$. But this refers only to the one reaction between FeO and CO. In reality the ores contain mainly the oxides Fe_2O_3 and Fe_3O_4, and the situation is much more complex. For the reversible reaction $Fe_3O_4 + CO = 3FeO + CO_2$ he gives the following table, showing the composition of the gas mixture in the state of equilibrium at various temperatures:

Temperature	Contents in Gas Mixture.	
Degrees Centigrade.	Per cent CO.	Per cent CO_2.
450	46	54
490	47	53
550	44	56
750	30.5	69.5
950	23	77

The ratio of CO to CO_2 has a maximum (0.887) at 490° C. In producing spiegel iron and ferromanganese, ores containing manganese are brought into the blast furnace; manganese is less noble than iron; the blast furnace gases will be in this case especially rich in CO. This shows that the composition of the blast furnace gases depends as well on the nature of the ores as on the temperature in the furnace. But the reduction of oxides by means of CO is not the only process which can take place in the blast furnace; sometimes the deposition of very finely divided carbon is observed. This is due to the reaction $2CO = C + CO_2$, which is also reversible. This reaction requires a catalytic agent; the author has studied this reaction first with nickel and cobalt as catalyzer, and later with iron. The results are given in forms of diagrams and tables.

Protection of Iron and Steel From Corrosion.—For preventing iron and steel from rusting, it is often coated with zinc, "hot galvanizing" being the method most extensively used. Electroplating with zinc is in use for special classes of work, and is extensively employed by the British admiralty for giving boiler tubes a thin flashing of zinc for the purpose of detecting flaws and protecting the tubes from corrosion during the time of assembling and erection. Sherard Cowper-Coles describes in the *Electrochem. and Met.*, June, a new process which is called "sherardizing." The first step is to free the iron from scale and oxide by dipping it in an acid solution, or by sand blasting. The articles are then placed in a closed iron receptacle, charged with zinc dust, which is heated to a temperature from 500° to 600° F. for a few hours and allowed to cool; the drum is then opened and the iron articles removed, when they are found to be coated with a fine homogeneous covering of zinc, the thickness of which depends on the temperature and the length of time. It will be observed that the temperature required to bring about this result is about 200° below the melting point of zinc. The low temperature required makes the process cheap, as compared with the process of dipping in molten zinc, and has the additional advantage that it does not deteriorate iron and steel of small section to the same extent as hot galvanizing. The whole of the zinc dust is consumed; there is no waste of zinc as in the hot galvanizing process. The zinc powder used is commercial zinc dust and should not be confused with zinc oxide; it is obtained during the process of distilling zinc from its ores. The receptacle in which the process is carried on is air-tight and the air exhausted so as to prevent the formation of too much zinc oxide; to prevent the iron receptacle from becoming coated with zinc, its inside is coated with plumbago or black lead. Articles coated with grease receive as good if not a better coating of zinc than those which are free from grease. The equipment of works for carrying out this process is described and illustrated.

Distillation of Zinc is a topic recently made the subject of exact thermo-electric temperature measurements by W. McA. Johnson (this journal, May, 1904, page 185), and also the subject of an interesting article in *Thonindustrie Zeitung* (1904, page 154). We take the following facts from an abstract in the *Revue de Metallurgie*, June, 1904. The temperature outside of the retorts, in the furnace, varies between 1067° and 1320° C.; the temperature of the charge rises in two hours to 814°, in eight hours to 1000°, where it remains constant for some time. This period of constancy corresponds to the period of rapid evolution of zinc, and is caused by the great absorption of heat in that reaction. Towards the end of the distillation, the temperature inside the retort rises to 1180° C. The losses of zinc amount to an average of 3 per cent in the residues, 1 per cent escaping through the condenser, 2 to 3 per cent escaping through the walls of the retort and a variable amount is absorbed by the retort itself. The latter loss may amount to 26 per cent of the zinc in the charge, for a fresh retort, and diminish to nothing at the end of seven or ten days, at the end of which time the clay of the retort has been entirely converted into zinc aluminate, while the silica remains in it as tridymite, in flat hexagonal crystals. The change of color of the retort material to a bright blue coincide with this transformation into aluminate.

LOCAL BRANCHES OF NATIONAL SOCIETIES.

A recent report of the Committee on Local Organizations of the American Institute of Electrical Engineers shows that there are twenty-nine branches of the Institute, in as many different cities. The average total attendance at these branches is stated to be over 1,300, while the attendance at the New York meetings of the central organization is not over 200. Consequently, through its branches, the Institute has increased its attendance at meetings, for the consideration and discussion of papers, more than six-fold. This result is especially gratifying, since it first was doubted whether the organization of local branches would have any other good effect, except the increase of membership. The latter result has indeed been accomplished to a remarkable degree.

The American Electrochemical Society has three local branches in New York, Philadelphia, and Madison, Wis. The meetings of these local branches were duly recorded in our columns. A report of the first meeting of the New York Section, with papers and discussions in full, may be found in the recently issued volume V. of the Transactions of the Society.

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

BY GEORGE P. SCHOLL, PH. D.

ELECTRIC FURNACE AND FURNACE PRODUCTS.

Electric Furnace.—C. P. E. Schneider, Le Creusot, France. Patent 763,330, June 21, 1904. Application filed December 22, 1903.

The furnace is a combination of the electric induction furnace and the electric melting furnace, for the purpose of melting the metal under treatment in the furnace itself, thus doing away with the necessity of a preliminary fusion of the metal in another vessel, as required in the inventor's former induction furnace, described in the July issue, 1904, p. 283. A longitudinal cross-section of the furnace is given in Fig. 1. It consists of a chamber *a*, which serves as a reservoir for the major portion of the metal. That part of the furnace in which the metal is to be heated by induction is constituted by a tube of

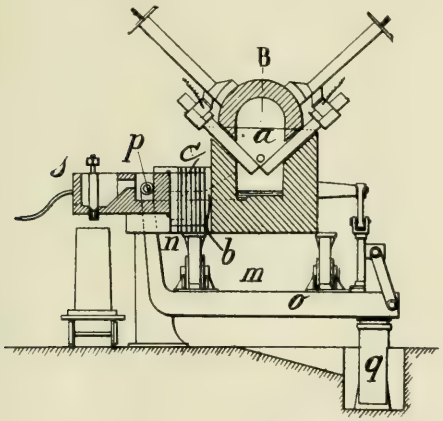


FIG. 1.—STEEL FURNACE.

small cross-section, both ends of which communicate with the chamber *a*. The heating of the metal in the tube is accomplished by two transformers *cc*, consisting of a magnetic circuit and a primary, while the tubes *b*, together with *a*, form the secondary. Two or more pairs of electrodes are introduced into the upper part of the chamber, so that they may be lowered, and the arc is struck either between the electrodes and the bath, or between the electrodes themselves. The furnace is supported on a movable platform and travels on rollers *m* by means of segments *n*. The rollers *m* are carried in their turn by a frame *o*, which rocks about the pivots *p*, the motion being produced by two hydraulic cylinders *q* and *r*. The tapping is done by means of a tapping way *s*, with spindle and plug, which communicates with the heating tube *b*.

Process of Electrolytic Manufacture of Aluminium.—Gustave Gin, Paris, France. Patent 763,479, June 28, 1904. Application filed May 14, 1903.

The process consists essentially in the electrolysis of a mixture of aluminium fluoride and sodium sulphide according to the formula $Al_2F_6 + 3Na_2S$, at a temperature of about 850° C. It is claimed that as soon as the mixture begins to melt, the constituents react upon each other with the production of sodium fluoride and aluminium sulphide, according to the formula $2(Al_2F_6 + 3Na_2S) = (Al_2F_6, 6NaF) + (Al_2S_3, 3Na_2S)$. The sulpho-aluminate $Al_2S_3, 3Na_2S$ has a much lower heat of formation than the other salt, and is stated to be alone decomposed by the current, the aluminium going to the cathode and the sulphur to the anode, while the sodium sulphide reacts upon the fluo-aluminate to furnish a new quantity of aluminium sulphide. The reaction in the latter case is given as: $(Al_2F_6, 6NaF) + 3Na_2S = Al_2S_3 + 12NaF$. Electrolysis is carried out with direct current of five to six volts and a current density of one ampere maximum per sq. cm. of active surface of the carbon anodes, and 2.5 amperes minimum per sq. cm. of cathode. The preparation of the electrolyte and the utilization of the various products resulting from the intermediary steps are intended to form a sort of continuous closed cycle. The raw material for the process is bauxide, which is dried, but not calcined, pulverized and subjected to the influence of a solution of hydrofluoric acid. The latter converts the constituents of the bauxite into aluminium fluoride, iron fluoride and aluminium fluosilicate and fluotitanate, from which solution the iron, silica and titanic acid are removed by adding hydrated alumina, the reaction being accelerated by being carried out at a temperature of about 60° C. The sulphur vapor disengaged at the anode is proposed to be burned in contact with the air and the resulting sulphurous acid transformed into sulphuric acid, either by the lead chamber or the contact process. This sulphuric acid is then utilized for obtaining hydrofluoric acid from the sodium fluoride, the reaction being $H_2SO_4 + NaF = Na_2SO_4 + 2HF$. This operation takes place in an apparatus, the sides of which are lined with bricks made of barium sulphate and agglomerated by means of coal tar, the bottom of the apparatus being heated to between 250° and 300° C. The remaining sodium sulphate is utilized in another furnace for the manufacture of the sodium sulphide required in the process, by reduction with carbon in a muffle furnace. The reactions as outlined call only for a consumption of bauxite and carbon, but it is admitted that in practice there are losses by slow volatilization of sodium fluoride and the carrying down of intermediate bodies with the precipitates. The losses of sodium and sulphur are made up by the introduction of a sufficient amount of pure sodium sulphate into the reduction furnace, and the fluorine is replenished by the introduction of hydrofluoric acid from an outside source. As advantages of the process are claimed, the doing away with the costly manufacture of pure alumina and the economy of electrical energy resulting from the electrolysis of aluminium sulphide, while avoiding the considerable difficulties in the preparation and preservation of the compound. The electrolyte is claimed to be easily handled and to satisfy all the conditions of density, fusibility and conductivity required for the manufacture of aluminium. Apart from the complications introduced by the various steps outlined above, not one of which is likely to take place as smoothly as represented by the formula, it is not clear how the actual electrolysis is to be carried out continuously, inasmuch as the sodium fluoride is constantly accumulating in the electrolyte. It is stated that it forms the residue of the electrolytic action and, as mentioned above, is used for the generation of hydrofluoric acid, and it would seem from that as though the process was to be run intermittently. This would, of course, be a great drawback in practical operation, and introduce serious practical complications.

Process of Smelting and Reducing Metals.—C. Diesler, Coblenz, Germany. Patent 764,044, July 5, 1904. Application filed January 12, 1901.

The process is based upon heating or smelting the materials

under treatment in a tightly closed vessel, the heat being supplied by an electric current. The furnace described consists of a cylindrical iron casing, open at both ends. At its bottom end there is introduced a tightly fitting cylindrical casting with an arched top, which latter forms the bottom of the heating chamber. At the top the vessel is closed by an arched cover. A tube of vitrified clay or other non-conducting material is arranged within the outer casing. The electrodes are introduced, insulated through the top and the bottom of the apparatus and are connected together by a carbon resistance for starting purposes. As an illustration of the application of the process to the production of calcium carbide, the inventor states that eighteen hundred kilograms of carbonate of lime, and seven hundred kilograms of charcoal, heated in an apparatus as above, from which the air has been withdrawn, will produce 1000 kilograms of calcium carbide and 1500 kilograms of carbonic gas. The metallic oxides and carbonates used in the process should not be employed in a finely divided form, but as coarse fragments, while coal and mineral silicates should be in finely divided form. The reaction is said to be facilitated when the materials to be treated are compactly pressed into the furnace. A manometer and draw-off cock for the gases are provided, the gases being utilized up to pressure of eighteen to twenty atmospheres within the furnace to facilitate the reduction of the materials treated, while the excess is led off. The principle of the process is stated as being based on the well-known fact that carbonates of metals are smelted in an air-tight furnace at a much lower temperature than in an open furnace, and while the oxides require a higher temperature than the carbonates, they are also smelted at a lower temperature in a closed vessel than in an open one, and on the further fact that the pressure produced by the gases evolved by the heat facilitates the combination and reduction of the materials under treatment.

Process of Manufacturing Vanadium and Its Alloys.—Gustave Gin, Paris, France. Patent 765,001, July 12, 1904. Application filed May 9, 1903.

The process consists essentially in the electrolysis of fluoride of vanadium dissolved in molten fluoride of calcium. The fluoride of vanadium is produced during electrolysis by the action of the fluorine upon the anode, which is composed of an intimate mixture of trioxide of vanadium and carbon. The anodes are prepared by mixing vanadium trioxide, obtained by the calcination of vanadic acid in presence of carbon, with finely powdered retort coke or petroleum coke and then adding a sufficient quantity of hot tar, so as to obtain a homogeneous and plastic paste by passing it through a kneading mill. The paste then passes through a mill, where it is crushed by very heavy steel rollers, after which it is pounded under stamps and then forced by hydraulic pressure through a draw-plate apparatus similar to those used for the manufacture of carbon electrodes. The prismatic or cylindrical blocks thus obtained are baked out of contact with the air, in a high-temperature furnace, and the electrodes thus obtained protected from contact with the air until they are required for use. The furnace used for the electrolytic operation is shown in the accompanying Fig. 2. The crucible Q of material unattackable by the electrolyte is filled with a bath C of calcium fluoride. The cathode A is water-cooled and a molten bath B of the metal with which the vanadium is to be alloyed rests upon it. The anode E is supported by a superstructure. When the apparatus is ready to work, the fluoride of vanadium or the fluoride of the metal with which the vanadium is to be alloyed is introduced into the calcium fluoride bath and the vanadium fluoride constantly reforms at the anode during electrolysis. The vanadium alloys with the cathode metal. For alloys with more than 25 per cent of vanadium the cathode section should be appreciably less than the active anode surface, good results and a sufficiently liquid bath being obtained with a medium current density of two amperes per square centimeter of active anode surface and six amperes per square centimeter cathode surface, and a pressure of between eleven and twelve volts. The metal fluoride introduced at the beginning, *f. i.*, ferric fluoride when iron-vanadium alloys are desired, only serves to start the operation, but it is desirable to add a certain proportion of it during electrolysis to compensate for the loss of a certain quantity of fluorine as gaseous carbon tetrafluoride. The iron, constituting the cathode in this case, is introduced in a metallic state and in small quantities at a

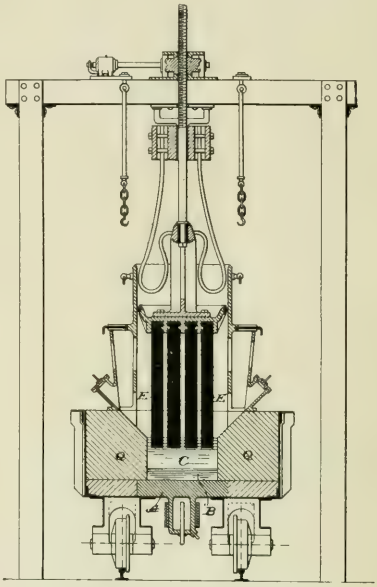


FIG. 2.—PRODUCTION OF FERRO-VANADIUM.

time after each tapping of ferro-vanadium. If no iron be introduced, almost pure vanadium may be obtained, but it is very difficult to tap the latter in a liquid state, and it has therefore to be removed from the furnace as a solid.

System for the Control of Electric Furnaces.—Woolsey McA. Johnson, Laharpe, Kansas. Patent 764,592, July 12, 1904. Application filed November 16, 1903.

The control of the furnace temperature in this system is obtained by connecting the wires of an electrical pyrometer, *f. i.*, of the Le Chatelier types, with a galvanometer, the indicating needle of which is preferably of platinum and insulated from the movable coil. The platinum needle is provided with a metallic contact dipping into mercury, the latter and the contact forming one terminal of a second circuit, the other terminal of which is connected to a movable block, which can be adjusted to any desired point on the scale of the galvanometer. This second circuit includes a storage battery and a solenoid with a soft iron core, which core carries a contact adapted to close a third circuit through the field of the exciter of the furnace dynamo when the second current is broken. When the second circuit is closed by the platinum pointer of the galvanometer touching the adjustable contact mentioned above, which has been set at the required temperature, the solenoid acts and throws a variable resistance and a magnetic cut-out into the circuit, which elements are so adjusted that the cut-out will break the circuit only in case the resistance proves insufficient to quickly reduce the furnace temperature.

Storage Batteries.

Secondary Battery.—James P. Clare, Quincy, Mass. Patent 762,882, June 21, 1904. Application filed October 31, 1902.

The inventor proposes to use an absorbent cellular substance, which is to be saturated with sulphuric acid and serve as retainer for the latter. As such, he uses the husk or outer covering of the cocoanut, which resists the destructive action of the sulphuric acid. It is prepared for use by being reduced to a granular form, preferably by grinding, washed in fresh cold water and dried. It is then soaked in sulphuric acid of the desired strength for battery work for at least 5 or 6 hours, and is then applied to the battery electrodes and the active material with a mild pressure, only sufficient to pack it against the exposed surfaces of the latter and keep them moist by capillary attraction.

Storage Battery.—H. C. Porter, Waukegan, Ill. Patent 763,321, June 21, 1904. Application filed November 25, 1901.

The inventor describes a battery, the positive plates of which have a grid with ribs having a W-shaped groove in cross-section. The lower part of the grid rests in a shoe or trough, preferably of hard rubber. The grid is packed full of active material in the usual manner, and is then enclosed in a sheath or envelope, preferably made of lead or a non-oxidizable lead alloy. The whole is then placed under a press, by means of which perforations are punched through the sides of the envelope in such a manner that the metal of the envelope which is displaced by these perforations is forced into the active material. The plate is then formed in the usual manner. The negative plates are without envelopes. A separator composed of a perforated sheet of insulating material, provided on both sides with ribs, serves to keep the positive and negative plates apart.

Battery Plate.—H. C. Porter, Waukegan, Ill. Patent 763,322, June 21, 1904. Application filed July 14, 1902.

The plate is cast in the form of a casing, with a terminal and a series of longitudinal ribs, dividing it into a certain number of pockets. The casing is cast so that it is open on one side. The pockets are filled with active material and the open side is then closed by the use of an oxyhydrogen burner and a small stick of lead. The sides are then perforated in an analogous manner to that outlined in the preceding patent.

Secondary Battery.—J. W. Madigin, Toronto, Canada. Patent 763,565, June 28, 1904. Application filed January 10, 1903.

The plates of this battery are formed out of sheet lead, being first perforated and then corrugated horizontally. They are then placed in a mold and a stiffening rim is cast or burned around them, after which the active material is parted through the perforations, so as to be flush with the rim on both sides of the plate. A plate of fibrous cellulose or wood fiber, which has been chemically treated with an ammoniacal salt, is placed between the plates. As the separator plates are porous, it is claimed that they draw the electrolyte by capillary attraction from the bottom of the cell up to the top of the electrodes.

Method of Separating Mechanically Entrained Globules from Gases.—Thomas A. Edison, Llewellyn Park, N. J., assignor to Edison Storage Battery Co. Patent 764,183, July 5, 1904. Application filed November 28, 1902.

The invention is intended to do away with the undesirable effects caused by the gases developed from storage batteries, especially at the end of the charging period. These gases are charged with finely divided globules of the electrolyte, which have been carried off mechanically. The method described consists in discharging the escaping gases at such a velocity and in such a manner, that they will be directed against a film of solution with sufficient force to overcome the surface tension of the latter; the entrained globules then coalesce with the film and permit the gases to escape in a substantially dry condition. The arrangement is illustrated in Fig. 3. The top of the battery receptacle 1 is provided with a neck 2, with a tight joint. This neck has a flat seat 3, upon which rests a mushroom valve 4, having a weighted stem 5. A casing 6, with vents 7, is screwed into the neck 2, and a small deflector plate 8 is arranged above these vents. A disc of wire gauze 9 covers the mouth of casing 6. A neck 10, with hinged cover 11, rubber packing 12, spring 13 for opening, and yoke 14 for closing the cover, is also provided. The check valve 4 is normally closed by its weight, until the pressure of the gases which have been accumulating in the top of the vessel is sufficiently high to force the valve open. The gases then rush at a high velocity against the base of the neck 2 and casing 6, and form a liquid film, which coats the base of the casing 6 and also deposits on the seat 3. As soon as the gas pressure has been relieved, the valve closes again and sticks to a certain extent to its seat, on account of the liquid film, in a manner analogous to the sticking of two glass plates together, if a film of liquid is interposed between them. If the valve is now raised again by the pressure of the gases, the latter impinge against the liquid film with sufficient force to overcome its surface tension and to cause the entrained globules of liquid to coalesce with the film and thus

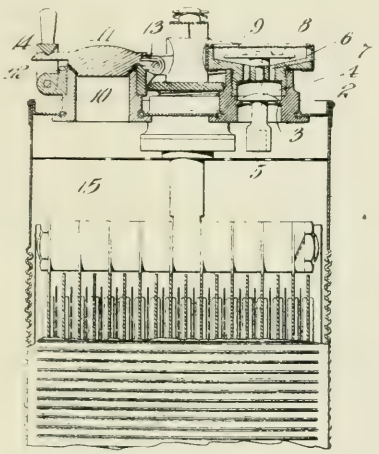


FIG. 3.—EDISON STORAGE BATTERY.

be separated from the gases. If for any reason the gas pressure should become so great in the cell, that a complete separation is not effected in the way just described, a further separation will be effected by their striking the dash plate 8. It is stated though, that the purpose of the dash plate is not particularly to supplement the operation of the check valve 4, but to cause the gases to be diluted and deflected, so as to pass through gauze 9 in a non-combustible condition. It has been found that, if the deflector is not used, the gases frequently pass through the vents 7 in a sufficiently concentrated form as to burn above the gauze, and when the gauze becomes too hot, an explosion takes place beneath it, which communicates with the gases in the cell and does serious damage. The neck 10 serves for replenishing the cell. A diaphragm 15 is preferably arranged, made of hard rubber and perforated. If such a diaphragm is employed and overcharging of the cell causes the electrolyte to froth until the diaphragm is reached, the latter is coated with a film which closes the perforations and effectually assists the operation of the check valve separator, as it acts in substantially the same manner as the latter. The surplus liquid, not retained by capillarity in the bore of the casing 6, will, of course, flow back again into the cell over the valve seat, when the valve opens again, so that it is only necessary to replenish the electrolyte from time to time with distilled water.

Battery Cell.—W. O. Duntley, Chicago, Ill. Patent 764,282, July 5, 1904. Application filed Feb. 15, 1904.

The invention is intended to facilitate the removal of sediment from the active material of the battery grids, which has fallen down to the bottom of the cell. The inventor supports the battery grids on staggered supports on the bottom of the cell and provides an opening, which is preferably circular, in the cell bottom. Various constructions are described, intended for a quick and efficient closure of the opening.

Storage Battery.—T. Kitsee, Philadelphia. Patent 765,082, July 12, 1904. Application filed August 9, 1902.

The battery comprises a containing jar, which contains a frame of hard rubber, slotted at the top and bottom, and having an internal flange extending all around the frame. A pair of supporting plates of porous material fit snugly against these flanges, thus closing the sides of the frame. The outer faces of the plates are provided with a series of projecting pins, arranged in a staggered fashion and acting as supports for a thin strip of lead, wound in zig-zag fashion on them, so that the outer edges of the strip are flush with the free ends of the pins. The ends of each strip project through openings in the top of the frame, and form the battery terminals. A body of active material is packed around the pins and conductors. Covering plates are provided to hold the active material in place, the inner sides of which, however, do not come into contact with the pins, the space remaining between the two being also filled with active material. One of the supporting strips and its pins will form the positive, and the other the negative electrode.

Storage Battery.—T. A. Willard, Cleveland, Ohio. Patent 765,060, July 12, 1904. Application filed August 13, 1903.

The object of the invention is to provide a non-conducting sheath or envelop for the electrodes. The sheath is preferably made of hard rubber, in the shape of a box open at the top. The side walls have a series of vertical ribs and are provided with numerous perforations for the circulation of the electrolyte. The peculiar shape of these perforations constitutes a principal feature of the invention. They are cone-shaped, the larger openings being on the inside of the sheath. To effect this, it is stated, the surface of the sheath is blown full of cone-like projections, the points of which are subsequently ground off. It is claimed that in this manner the sheath is not deprived of any elasticity or structural strength as in the ordinary practice of making perforations, and that the peculiar cone-shape of the openings renders them good supports for the active material.

Galvanic Elements.

Electric Battery.—P. J. Kamperdyk, New York. Patent 763,674, June 28, 1904. Application filed October 14, 1903.

The object of the invention is to provide a carbon electrode of great superficial area. For this purpose a number of carbon balls are strung like beads on copper wires coated with an incorrodible metal as platinum, the wires being joined at the upper and lower ends to copper plates, which are protected against corrosion by a layer of lead or a coating of cement. They are enclosed in porous cups, supplied with depolarizing liquid. The negative electrodes consist of two flat zinc plates, immersed in the battery electrolyte and held close to the walls of the cups by distance pieces. Several alternative carbon electrode constructions are shown, embodying the same principle as the above.

Method of Converting the Energy of Fuel into Electrical Energy.—Hugo Jone, Chicago. Patent 764,595, July 12, 1904. Application filed November 7, 1901.

The object of the invention is to obtain electric energy from fuel by means of a galvanic cell. The latter consists of a rectangular vessel, the material of which is not affected by caustic potash. An iron plate with a ledge running around its edge, thus forming a sort of flat pan, rests upon the bottom and forms the receptacle for the positive electrode of tin, either solid or melted. A square vessel of porous carbon, as wide as, but considerably smaller than, the rectangular vessel, rests upon the latter by means of a flange and is insulated from it. This vessel serves as the negative electrode and contains a mass of mercuric oxide which acts as depolarizer. The flat pan mentioned above is only a little longer than the porous-carbon vessel, and the space in the containing vessel, not occupied by the two, is partitioned off by a porous plate, which may be made of sulphide of calcium, and a sliding door. In the space thus partitioned off is placed another porous vessel. The battery electrolyte is caustic potash, and the temperature at which the battery is operated may be considerably below 300° C., and as low as 150° C., in which latter case the tin electrode is no longer fluid. In the operation of the cell the mercuric oxide is stated to be reduced to mercurous oxide, while the tin is converted into stannous oxide, which is gradually dissolved in the electrolyte to stannite of potassium. The latter diffuses through the partition mentioned above into the other part of the vessel, the sliding door being open. In the second porous vessel the stannite of tin is precipitated by a hot concentrated solution of barium hydroxide, the sliding door being closed at the time when the addition of the barium salt is made, so as to prevent the barium stannite from passing into the other compartment and covering the surface of the metallic tin. The barium stannite is allowed to accumulate in the porous vessel and removed from time to time. It is reduced to metallic tin in a reverberatory furnace by means of coal or some other suitable fuel, the waste gases from the coal being utilized for furnishing heat to the battery cells. The barium oxide thus obtained is dissolved in hot water and is available for use again, while the metallic tin is also returned to the cell. The mercurous oxide obtained by the operation of the cell is allowed to accumulate until nearly all the mercuric oxide is converted into it. It is then removed and a new quantity of mercuric oxide put into its place. The mercurous oxide is treated in a retort with concentrated nitric acid, so as to convert it into mercuric nitrate. Steam is then admitted into the retort and the mercuric nitrate decomposed according to the equation $Hg(NO_3)_2 = HgO + 2NO_2 + O$. The nitrogen peroxide thus evolved is carried into a condenser coil and air is admitted to it, thus converting it into nitric acid, which may be used over again. The waste gases from the heating of the retort are also utilized to furnish heat for the cells. It is stated that stannic oxide or stannite of potassium is not formed in the electrolytic oxidation of the tin, or at least to a very limited extent, if the oxygen of the air is excluded and the cells are kept at a constant elevated temperature. If the cells were allowed to cool, the potassium stannite would be liable to form stannate, which would require a much higher temperature for reduction than the stannous compound. It is claimed that the removal of the battery product, the stannous oxide, prevents the action of the battery from being stopped by saturation of the electrolyte with stannous oxide, coupled with accumulation of stannous oxide on the surface of the metallic tin. The electromotive force of the cell is given at 1.03 volts and the current strength of a cell of the capacity of one gallon of liquid as twelve amperes, when the external resistance is 0.04 ohm.

Galvanic Battery.—C. B. Shoenmehl, Waterbury, Conn. Patent 764,826, July 12, 1904. Application filed November 2, 1900. Patent 764,827, July 12, 1904. Application filed July 23, 1901.

The battery of the first patent is of the zinc-copper oxide type, the zinc element having a ring-shape. The copper oxide is contained in a conical, perforated basket, larger at the top than at the bottom, means being provided for lifting the basket out easily and cleaning it. In the second patent the form of the zinc electrode is the same, but the form of the conical basket has been changed. A perforated cone is now placed on the bottom of the basket, with its largest side down. Thus,

both sides of the receptacle for the copper oxide are now tapering, with the result that the material can quickly free itself when the receptacle is open and inverted. Besides, both exterior and interior surfaces are exposed to the action of the electrolyte

Electric Battery.—P. J. Kamperdyk, New York. Patent 764,813, July 12, 1904. Application filed December 26, 1902.

The invention relates especially to the zinc pole of primary batteries, which is shown in the form of a plate. The latter is produced by placing a frame consisting of a series of copper wires covered by electrolysis or otherwise with a coat or plating of a non-corrodible conducting material as platinum into a mold, which is then filled with melted zinc. The latter entirely encloses the wires, which thus serve as support for the zinc plate and permit it to be used much longer than ordinary plates.

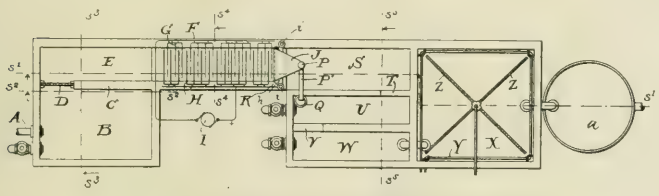


FIG. 4.—APPARATUS FOR TREATING SEWAGE.

MISCELLANEOUS.

Apparatus for Treating Sewage.—W. J. Schweitzer, White Plains, N. Y. Patent 763,026, June 21, 1904. Application filed July 31, 1903.

A plan-view of the proposed apparatus is given in Fig. 4. It comprises a receiving tank B, which is fed by pipe A. The receiving tank contains a baffle wall C, which breaks the force of the flow and directs the material through the screen D, which breaks up the semisolid matter contained in the sewage. The flow then passes into the settling tank E, where sand, silt, etc., are deposited. From there it enters the electrolyzer F, where are arranged a series of negative electrodes G and positive electrodes H. They are preferably in the shape of a comb, having teeth which are trapezoidal in cross-section, the shorter side of the trapezoid teeth being arranged facing the direction in which the liquid is flowing. Each alternate plate has its teeth in staggered relation to the next contiguous plate in the series. The electrodes, if of cast iron, should be galvanized. The sewage is stated to be generally sufficiently saline to contain enough sodium chloride so as to disinfect the liquid thoroughly by the chlorine liberated by electrolysis. Common salt may, however, be added in the chamber B. The best results are said to be obtained with a current of five volts and three amperes per gallon of solution, no further data as to current density being given. Fatty matters rise to the top in the electrolyzer, and are removed by skimmer J into pipe P, which connects with a trough P′ leading into tank Q. The liquid flows very slowly from the electrolyzer over wire R into tank S, over wire T into tank U, and over wire V into tank W, for the purpose of settling and precipitation. From there it goes to the settling chamber X, where it is treated with a weak solution of lime injected by pipes L, perforated in supply pipes Y, being placed along the outer walls of the chamber. From the settling chamber X the liquid goes to a sand filter a, and is then discharged into a stream or in any suitable manner.

Process of Electrically Extracting Essential Oil.—G. D. Burton, Boston. Patent 763,151, June 21, 1904. Application filed June 27, 1898.

Apparatus for Making Extracts by Electricity.—Same inventor. Patent 763,152, June 21, 1904. Application filed same date as above.

The object is to facilitate and hasten the operation of extracting essential oils from bark or other vegetable matter. The apparatus comprises an extraction tank provided with a conical hood, from the top of which a pipe leads to a condenser, which, in its turn, is connected with a receptacle. The electrodes in patent 763,151 consist of a pair of transverse plates, at opposite sides of the extraction tank. A perforated guard plate prevents the material under treatment from coming into contact with the electrodes. In carrying out the process, the material from which the essential oil is to be extracted, *f. i.*, tanbark, is placed in bags and brought into the tank. The latter is filled with water or any suitable aqueous solution, and a current is passed varying according to the size of the tank and ranging from 400 to 500 volts, and from 100 to 150 amperes; the current density is not given. The tank may be provided with a coil of perforated pipes for supplying air or steam under pressure for agitating the loose material in the tank. The apparatus shown in patent 763,152 is substantially the same, but the electrodes are arranged quite differently. Instead of being constituted of two transverse sheets as above, they are composed of transverse conductors, preferably in the form of rods or tubes. They are arranged on opposite sides of the tank and are connected with each other by longitudinal, perforated tubular conductors. Consequently, only the heating effect of the current is utilized in this apparatus and a current of comparatively low voltage and high amperage is employed from 2½ to 10 volts, and from 1000 to 1500 amperes. The material, *f. i.*, tanbark, is again placed in the apparatus inclosed in porous bags, into a liquid consisting of water and sodium chloride or other suitable solvent, of a specific gravity of 1.03 to 1.05. The vapors from the heated liquid are condensed in the condenser and thence pass to the receptacle.

Magnetic Ore Separator.—F. J. King, Croydon, England. Patent 765,013, July 12, 1904. Application filed March 31, 1902.

The distinguishing feature of this invention is the preliminary treatment of magnetic ore, by passing it over an inclined table, below which are arranged a series of transverse magnetic bars, connected alternately to the opposite sides of a series of very powerful electromagnets. In this way very strong and uniform magnetic fields are set up between the bars, and the ore passing over them becomes stratified, as it were, as the magnetic particles turn on their axes as they change from field to field, and thus gradually work their way to the top of the ore. After this treatment the ore is subjected to the influence of the separating magnets, which attract the magnetic particles, which now form the top layer of the ore. A belt passes over the magnet poles and carries the magnetic portion off, while the tailings drop right down at the end of the inclined table. The inclination of the table is adjustable in order to suit different materials.

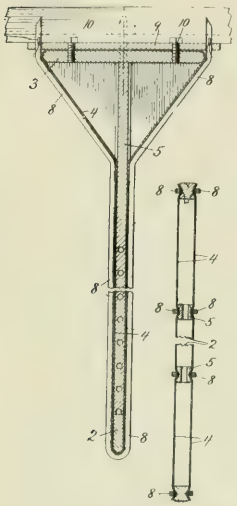
Electrochemical Gas Lighter.—Ignatz Rothstein, Berlin, Germany. Patent 760,567, May 24, 1904. Application filed May 12, 1903.

The gas lighter is provided with a small battery, the poles of which are connected by a short platinum wire. A number of thin platinum wires in the form of a cone extend from this short wire, the apex of the cone being situated at the wire and the outer ends being supported by an arm, extending from a shell which is situated on the battery conductors. The short wire becomes hot when the circuit is closed and renders the thin platinum wire cone incandescent, whereby the gas is ignited.

RECENT METALLURGICAL PATENTS.

Wet Processes.

O. P. Ankeny (patent 764,973, July 12), describes details of construction of filter presses for separating slimes from the liquid, in connection with the cyanide process. The apparatus contains, as usual, a number of filtering cells, consisting of a peripheral frame about which a canvas is stretched. A vertical cross-section of such a cell is shown in Fig. 1, and a horizontal cross-section in Fig. 2. In forming such a cell, the canvas 4 is folded at the middle point of its length about the lower bar 2 of the frame and brought up on opposite sides, the upper ends of the side bars having flaring portions. The ends of the canvas 4 are folded over the edges of the top bar 3, and clamped thereto by the clamping plate 9, which is secured to the top bar 3 by bolts 10. Spacing bars 5 are provided which extend across the cell from top to bottom at intervals of a few inches. These bars have the same width as the bottom bar 2. The edges of these spacing bars are grooved and U-shaped clamps 8 press the filtering web into the grooves of the spacing bars.



FIGS. 1 AND 2.—FILTER PRESS CONSTRUCTION.

G. Moore (764,486, July 5) patents "the process of filtering slimes and the like, consisting in immersing a filter in a bath containing the slimes and a fluid in which they are suspended, forcing said fluid through said filter by difference of pressure between opposite sides thereof, whereby the slimes are deposited thereon in a layer of the requisite character; removing the filter from said bath and cleaning it by air-pressure applied to the back thereof."

J. Smith (764,870, July 12), patents a horizontally-set rotary apparatus for the treatment of ores by the cyanide process. Such ores are frequently too heavy to be worked by ordinary extraction in upright apparatus, since the great specific gravity of the materials continually causes them to sink to the bottom and clog the machinery. A cross-section of the revolvable drum is shown in Fig. 3, showing the shelves, riffles or agitators 12, distributed around the internal periphery of the drum. The supply of oxygen (necessary for the solution of the precious metals in the cyanide solution) is provided for by the air-trap 14. It is a chamber with an opening 15 to the atmosphere. From this chamber leads a coil of pipe 16 which runs around the periphery of the drum and terminates with an open end at 17.

Furnace Processes.

R. Baggaley (764,332, July 5) patents a Bessemer converter for treating copper matte which can be cooled with air, while the extent of the cooling and the place of its application may be regulated as desired. For this purpose a series of ventilating air passages open to the atmosphere above and below is provided, the inlet being lower than the outlet.

C. W. Speirs (765,299, July 19), patents mechanical details of crucible furnaces which can be tilted for discharging the molten contents of the crucible without removing the same from the furnace. The object of the details of construction described by the inventor are to improve the means for supporting the crucibles in the furnace, to improve the combustion in the furnace, to retain the external parts of the furnace relatively cool, and to prevent as far as possible the escape of the products of combustion into the building in which the furnace is situated.

R. Robinson (765,323, July 19) patents details of construction of a refining furnace. Three flues are provided at each end of the furnace, the two outer ones being for the introduction of the flame to the melting chamber, while the center ones

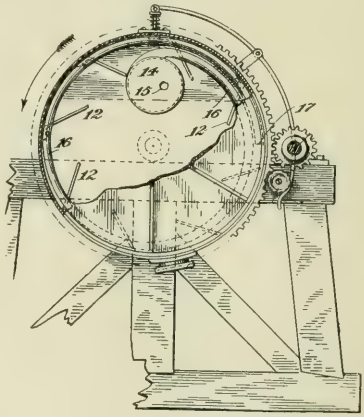


FIG. 3.—ROTARY APPARATUS FOR LEACHING ORES.

are openings leading to the draft-stacks for carrying off waste heat and spent gases. There are provided two upright standpipes on each side of the furnace having nozzle-shaped extension pipes which point toward the center of the melting chamber. Arranged on each of these nozzle-shaped pipes are adjustable twyers that, when in use, are lowered into the molten mass of the metal, and a forced draught of the air and gas, or of steam and gas and air is introduced into the molten gas to burn out the impurities.

C. W. Bray (763,847, June 28) patents a heating furnace for the reheating of plates and sheets, such as the packs formed in the reduction of black plates and sheets for tinning. The object of the details of his construction is to apply the heat evenly and uniformly to the metal while resting upon an endless carrier of annular form. An automatic intermittent movement is imparted to the carrier which moves step by step, allowing the insertion of a series of sheets during each interval of rest.

J. Hirschmann (763,892, June 28) patents a furnace for heating slabs or bars, such as tin-plate bars. The object of his construction is to carry the bars through the furnace and eject them, without causing marks on the plates which have occurred where water-cooled pipes are used for supporting the plates or moving them through the furnace.

Current Notes.

American Electrochemical Society.—At the July meeting of the Board of Directors the following gentlemen were elected members of the Society: H. E. Eggers, Santa Cruz,

Cal.; George G. Hitchcock, Claremont, Cal.; F. L. O. Wadsworth, Morgantown, W. Va.; William C. L. Eglin, Philadelphia, Pa.; E. Humblot, San Francisco, Cal.; P. McN. Bennie, Niagara Falls, N. Y.; J. W. Best, Denver, Col. At the August meeting of the Board of Directors the names of the following gentlemen will come up for election: Joseph Clark, Jr., Stanley, Idaho; Benito Herrera, Los Angeles, Cal.

New Mining Journal.—The first number has just been issued of the *Mining Magazine*, "an international monthly review of current progress in mining and metallurgy." The publisher is Mr. W. J. Johnston, the former proprietor of *Electrical World*, and later of the *Engineering and Mining Journal*. The editors are Dr. H. Foster Bain, Mr. Henry S. Fleming, Mr. Edwin C. Johnston and Mr. William Young Westervelt. The general policy of the paper is to provide the mining industries with a monthly journal corresponding in scope and character to the *Engineering Magazine* in general engineering. The first issue of the *Mining Magazine* is very creditable and contains articles by John A. Church, F. L. Ransome, C. Henrich, H. S. Fleming and W. R. Ingalls, the latter giving interesting notes on the metallurgy of copper, lead and zinc. A special feature is a very useful "Mining Digest," being a condensation of important articles from the leading technical periodicals; it has evidently been prepared with great care. Electrochemical Industry wishes every success to the new enterprise.

Correspondence.

ELECTROMETALLURGY OF IRON AND STEEL.

To the Editor of Electrochemical Industry:

With respect to your article on the electrometallurgy of iron and steel, published on pages 280 and 281 of your July issue, permit me to call your attention to an error in the statement of the selling price of the La Praz electric steel given in the abstract of my preliminary report to the Honorable the Minister of the Interior. The sentence in question should read: "The selling price of the steel varies from $363.60 to $123.60 per ton, depending upon quality."

If given in francs the figures per ton of 2000 pounds are 1,818 francs and 618 francs, respectively.

Eugene Haanel.
Ottawa, Canada. Superintendent of Mines.

Book Reviews.

Ready Reference Tables.—Vol I.: Conversion Factors of every unit or measure in use. By Carl Hering. New York: John Wiley & Sons. 196 pages. Bound in flexible morocco. Price $2.50.

This is a "dear" little book. Considering simply its size and weight, the first impression will probably be that it is very expensive. A more intimate acquaintance with the book and its steady use for several weeks should, however, convince the owner that, like all good and expensive things, it is many times worth its price.

The features which make this reference book especially valuable are completeness, thoroughness, accuracy and consistency. It does not appeal to a single class of engineers, but to all of them. While adapted specially to the use of American and British engineers and physicists, etc., it also gives foreign units and measures, and is not restricted to those in use at present, but also gives obsolete units. This will surely be appreciated by all who have to refer occasionally to foreign or old literature. It may be that, for the sake of completeness, the author has gone a little too far and has given unusual and obsolete units which may never be looked up by anybody. Yet this completeness of the tables will be thoroughly appreciated whenever one comes in practice across an unusual unit for the meaning and value of which one would look in vain in other books.

The aim at completeness accounts partly for the great length of some of the tables. There are, however, two other factors which cause the great intricacy and complexity of our system of units and measurements. One is expressed by Lord Kelvin in the following words which the author has placed at the head of his preface: "I look upon our English system as a wickedly brain-destroying piece of bondage under which we suffer. I say this seriously. I do not think any one knows how seriously I speak of it." This source of complexity of our systems of units would, of course, be removed by the general and consequent introduction of the metric system and c. g. s. system.

Yet, there is another factor which causes complexity and which will render conversion-tables always necessary. We will always have gravitational units, heat units, electrical units, light units. The energy of a waterfall is most conveniently given in kilogram-meters, the power of a dynamo in kilowatts, etc.; and for the conversion from one system to another we will always need conversion factors. By the way, the relations which exist between the groups of gravitational, heat, light, and electrical units are represented on page 3 in a simple diagram, which is evidently a home-made affair, but is very instructive.

The thoroughness with which the book has been prepared is emphasized by the fact that, as the author says in the preface, the conversion factors are not compiled but have all been especially recalculated from the exact legal values as far as such values exist, and from the very best, most standard, and most authoritative values attainable, when no legal values existed, and that the greatest possible care was taken in selecting these fundamental values. The authority for each fundamental value is given in the book, and since all conversion factors were calculated from the same set of fundamental values, they are all consistent with each other, forming a single, inconvertible uniform system.

Concerning the accuracy to be expected, the author states that the calculations were very carefully made, in many cases by two entirely different methods, and the resulting values were checked and cross-checked, often several times. For most of the values a final comparison was made between the electrotyped plates and the original calculation sheets. A special feature is that a great many of the conversion factors were checked by authorities, especially members of the staff of the National Bureau of Standards, etc. All these figures are marked with an asterisk, and all these values were checked again by the original authorities after the pages were electrotyped.

The author has adopted the general system to give six places of figures and seven of logarithms. Here it may again appear that he has gone too far, since in many cases the accuracy of some of the fundamental figures is not sufficient to warrant giving six places of derived figures. The author, however, heads off this criticism by saying that he has maintained the system uniform throughout the tables in order to enable changes to be made by mere proportion, when more accurate fundamental values become attainable in the future. An admirable feature has been added in the form of convenient approximate values consisting often of only one, and generally of only two digits. These digits are so chosen that they reduce the calculation to the simplest possible; they will suffice for most of the ordinary computations, being always correct within 2 per cent.

It is impossible to give in a review, which must be necessarily short, an idea of the full scope of the tables. We will briefly give the contents. The introduction (twenty-six pages) deals with the inter-relation of units; compound names of units; distinction between units and quantities measured in

those units and the reduction of formulas from one kind of units to another (these pages are worth reading, although they deal with very elementary subjects); ratios, percentage, condensed numbers, accuracy of approximate or abbreviated numbers, accuracy of logarithms, absolute system of units, dimensional formulas, decisions of international congresses The introduction is concluded by a full table of the various physical quantities and relations, giving name, symbol, derivation, dimensional formula and c. g. s. and practical units. This table is based on that of the committee of notation of the Chicago International Electrical Congress, but is far more complete.

Then follow the tables of conversion factors. Twelve pages deal with lengths, 4 with surfaces, 11 with volume, 6 with weights or masses, 8 with weights per length, weights per surface (pressures), weights per volume (densities), followed by tables of weights of water and volumes of water. Seven pages deal with energy, work, heat, 4 with power, followed by tables of forces, moments of inertia, linear velocities, angular velocities, frequencies, linear and angular accelerations, angles, solid angles, grades, time, flow of water.

Forty-eight pages deal with electric and magnetic units (among them brief chapters on electrochemical equivalents and electrochemical energy, and tables of electrolytic deposits in mass per time). Then follow 5 pages of light units and a full table (14 pages) of thermometer scales, giving the relations between degrees Centigrade, degrees Fahrenheit, degrees Reaumur and degrees of absolute temperature, and a concrete scale which is a novel and very useful feature. It gives numerous temperatures at which various materials boil or melt, thus enabling one to so maintain or measure these temperatures. Exactly this method has recently been made use of in the thermometric department of the National Bureau of Standards. Most of these figures are only approximate, although they have been compiled from the best authorities. There are, however, some rather large discrepancies; the worst is in the case of the melting point of manganese, which is given twice, once as 1900° C., and the other time as 1245° C., the latter is stated to be the melting point of manganese 99 per cent pure, as determined by Heraeus (probably manganese free from carbon, obtained by reduction with aluminium). These inconsistencies, of course, are not the fault of the author; they emphasize the importance of redeterminations of melting points and boiling points with the use of pure materials. The book is concluded by some tables of money, money per length and money per weight, scales of maps and various useful numbers, and a very complete index of twenty-two pages.

The book is thoroughly up-to-date, in some cases (for instance, "abvolts," "abstatvolts" among the electrical units), even ahead of the times. In the conversion tables all the various measures used in practice, more especially by engineers and physicists, are given with their values in terms of as many of the others as they are likely to be converted into in practice; the reciprocals of these are also given, thus enabling every calculation involving the conversion of one measure into another to be reduced to a single simple multiplication. each table is preceded by a short introduction; the explanations given there are brief and to the point and well worth reading. The somewhat mysterious remark on pages 128 on the Gibbs-Helmholtz equation would have been clearer if this equation had been given and explained this could be done in two lines.

The reviewer has used the book constantly for about seven weeks, in the average about twenty times a day. Only in two cases he did not find directly what he was looking for. The first case was when he wanted to convert the figure of specific electric resistance given by an American manufacturing company in ohms per cubic inch into ohms per cubic centimeter. Ohms per cubic inch are not given in the table (page 103) for specific resistance. Of course, the conversion is the same as from inch to centimeter (page 30). The other case was when the reviewer wanted to find the value of one heller (an Austrian coin). The book states on page 164, under Austria-Hungary: 1 krone = 0.203 U. S. gold dollar. "The small unit is the heller." There is no conceivable reason why it should not state directly that 1 krone = 100 heller. But this is the only vague statement which the reviewer has found in the book. The arrangement of the various subjects is very convenient, and with the aid of the extensive index it is easy to find quickly what one is looking for. Print and mechanical make-up are excellent. The book is of such size that it may be carried conviently in the pocket. It appears as volume I. of "Ready Reference Tables." If the following volumes turn out to be as valuable as the first one, the serial will form one of the most handy and indispensable reference works for every engineer and scientist. For the present we ought to be grateful to the author for what he has given us in volume I.

Transactions of the American Electrochemical Society.—Vol. V. Philadelphia: American Electrochemical Society.

This volume covers the proceedings of the fifth general meeting, held at Washington, D. C., from April 7 to 9, of this year. It is an attractive-looking volume of 284 pages and contains as frontispiece an excellent portrait of the new president, Prof. H. S. Carhart. It contains the papers and discussions in full, concise abstracts of which were given in our May issue. A paper by Mr. Voege, which was not read at the meeting, on account of limitations of time, and which is now printed in the Transactions, is abstracted at some length on another page of our present issue. The volume also contains the proceedings of the first meeting of the New York section, a report of which was given in our February issue.

The Committee on Publication should take a little more care in editing the discussions. Surely, not the whole discussion of Mr. Addicks' paper was "communicated before the meeting" as indicated on page 122. Everybody has a right to consider the electronic theory either as ridiculous or as the foundation of new developments, as he pleases; but the theory should not be made unnecessarily mysterious. The equation given in Dr. Gahl's remark on page 146 is a Chinese puzzle; this is not Dr. Gahl's fault, but evidently due to the fact that the printer had not the proper type for electronic charges; hence something else was printed. The first remark of Mr. Hering, on page 118, appears senseless, simply because some remark of somebody else has been left out to which Mr. Hering replied. It is inherent in human nature that in a discussion one sometimes makes a remark which he would not like to see in print. In revising the discussion the remark is suppressed, but the Committee on Publication should see that such suppression of remarks should not destroy the sense of replies made afterwards by other speakers. Other similar examples could be pointed out.

The Electric Furnace. By Henri Moissan. Authorized translation by Victor Lenher, Ph. D., Easton, Pa.: The Chemical Publishing Co.; 305 pages. Price, $3.00.

It is somewhat surprising that seven years have passed since the publication of "Le Four Électrique" before the appearance of an English translation. The original book marked an important point in the history of chemistry, since Moissan's work undoubtedly gave a new stimulus to the study of inorganic chemistry. Organic chemistry possesses great attraction for chemists, because of the interminable series of new compounds which may be produced; while in the case of inorganic chemistry it is by no means so easy to obtain something new. Moissan, however, by developing the use of the laboratory electric furnace, put a new tool in the hands of the chemist and opened a fresh field of great interest for investigation and research.

Anyone who has had experience in translation from one language to another realizes the difficulty of avoiding such literalism as has a bad effect on the language of the transla-

tion. This difficulty is unfortunately conspicuous in Dr. Lenher's work. The absence of an index also seems inexcusable in any scientific book published in America.

Besides being a translation of "'Le Four Électrique" as it was published at Paris, in 1897, the present book contains interesting additional material supplied to the translator in manuscript by Professor Moissan. For example, under carbides, compounds of carbon with the following elements are found: Potassium, sodium, neodymium, praseodymium, magnesium, glucinum and iron. Under silicides: Manganese, nickel, cobalt and platinum. Under borides: Calcium, strontium, barium, nickel, cobalt and glucinum. There is also a description of certain phosphides, such as those of the alkaline earths, iron, chromium, nickel, etc.; and of arsenides of the alkaline earths.

In writing his book on the electric furnace Professor Moissan has spared no pains to explain thoroughly the manipulation of his furnaces, the methods of performing his experiments, and the analysis of the resulting products, and for this reason the book should be in the hands of all who are engaged in investigations of the chemistry of high temperatures. Moreover, the work is full of suggestions for further study and of methods which are generally applicable to the working out of new problems.

One of the most interesting portions of the book is the study of the various modifications of carbon which culminated in the production of artificial diamonds. The great interest attaching to the final achievement has perhaps caused less attention to be paid to the preliminary work than it deserves.

In spite of the immense amount of valuable work Professor Moissan has done in this direction, the subject is by no means exhausted, nor can it be said that he has definitely proved all his statements. Berthelot has recently shown (*Comptes Rendus* CXXXVII., page 589) that the film formed on the globe of an incandescent lamp which has been in use for some time contains no graphite. Moissan, on the other hand, describes experiments in which he found that the film on the globe contained graphite, and comes to the conclusion that "when gaseous carbon assumes the solid condition it always gives graphite."

As another example of a doubtful point: Moissan illustrates the vaporization of carbon by heating the outside of a carbon tube containing a boat filled with silicon, with an arc, and describes the formation of silicon carbide from the combination of the vapors of silicon and carbon. Acheson, on the other hand, has shown that by heating silicon carbide to a very high temperature, the silicon is vaporized, leaving the carbon behind as graphite, which has the exact form of the crystals of silicon carbide.

As an example of a direction in which further investigation may proceed, reference may be made to the formation of double carbides, such as glucinum borocarbide, prepared by Lebeau and described. So far little has been done in this direction, though the results would undoubtedly be of considerable scientific interest, and might possibly lead to the development of valuable industrial products.

No one engaged in work with the electric furnace can afford to be without this book.

Analtical Chemistry: Vol. II., Quantitative Analysis, by F. P. Treadwell. Authorized translation from the second German edition by William T. Hall; 8 vo., pp. 654; price $4.00. New York: John Wiley & Sons, 1904.

Since Professor Treadwell's removal to the Polytechnicum at Zurich, German-speaking students have been reaping the benefit of his instruction, but this translation again brings him into contact with his former American students.

The work is divided into five sections; viz., general directions, gravimetric determination of the metals, gravimetric determination of the metalloids, volumetric analysis, and gas analysis. The ground covered is so broad that a complete treatment of the subject is impossible in one volume; as a necessary result we have therefore a book of great value in giving to the student his first practices in the important determinations of quantitative analysis, but of almost no value to the advanced analytical chemist. We unhesitatingly recommend the book as probably the best in the English language for the use of students, or for a beginner in the subject wishing to learn quantitative analysis by self-instruction.

ST. LOUIS EXPOSITION.

Exhibit of Baker & Co.

The exhibit of Messrs. Baker & Co., Inc., the well-known platinum, gold and silver manufacturers and refiners, of Newark, N. J., is in the Mines and Metallurgy Building, block No. 40, and is under the direct supervision of the United States Government.

The display, an illustration of which is herewith given, will

EXHIBIT OF BAKER & CO.

be found especially interesting to electrochemists, chemists and metallurgists, as it includes platinum and the different metals and salts of the platinum group, a large variety of manufactured platinum ware, platinum rivets, sparking points and platinum in its various forms as applied to the arts and industries.

Chemical Exhibits of the German Government.

Under the auspices of the German Government, the chemical manufacturers and scientists of Germany have prepared a very extensive and highly interesting exhibit, the leading idea being to show the development of chemistry in Germany. Besides thirty-nine chemical manufacturers and twenty-five makers of chemical apparatus, 117 professors and instructors of universities are represented by exhibits. The exhibit is in the electricity building and contains a reading-room, an alchemistic laboratory, Liebig's laboratory, the exhibits of general and inorganic chemistry, pyro-chemistry, balances, electrochemistry, organic chemistry, dyeing laboratory, and physiological chemistry. The exhibition is very well arranged and contains much of special interest to electrochemists and electrometallurgists. We hope to give in our next issue a fully illustrated description of those parts of this exhibition which should especially appeal to our readers.

Exhibit of the Roessler & Hasslacher Co.

The Roessler and Hasslacher Chemical Co's. exhibit is to be found in the Palace of Liberal Arts, Block 66. The products of the company are shown in a most instructive and, at the same time, interesting grouping, their booth representing the painting by D. Teniers, Jr., "The Old Alchemist."

GAS BLOWERS AND EXHAUSTERS.

The adjoining diagrams show modern types of gas exhausters made by the Buffalo Forge Company, of Buffalo, N. Y., for use in chemical and electrochemical works. Since they are used for removing acid and other chemical fumes, they require an interior construction impervious to the action of the gases handled.

Fig. 1 illustrates a special type of exhauster designed for use under moderate pressure. This exhauster was originally designed and constructed under patent 602,770 for exhausting

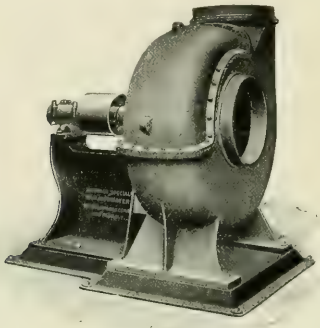


FIG. 1. STEEL-PLATE FAN COATED WITH LEAD

acid fumes of a character very injurious to the regular steel plate or cast iron fan or exhauster. This apparatus is cast of an alloy made up of antimony and lead, no steel or iron being used in the construction. Exhausters of this type are of great service in chemical and electrochemical plants, fertilizer works, etc. The construction is such that easy excess may be had to the blast wheel.

Fig. 2 shows another special type of exhauster, suitable for use along the same line. It is of steel plate construction, but

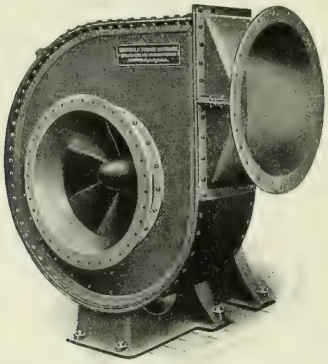


FIG. 2. EXHAUSTER, SHOWING SHEET-LEAD LINING

designed for a sheet lead coating, which metal is not affected to any extent by the action of acid fumes. In many cases, the blast wheel is made entirely of an alloy cast of a spider frame. These exhausters can handle without injury fumes which attack steel and cast iron.

This type of exhauster may also be lined with sheets of pure copper and the blast wheel is often constructed of the same material. Where it is found absolutely necessary, exhausters built with steel plate shells may be lined with a heavy coat of glass.

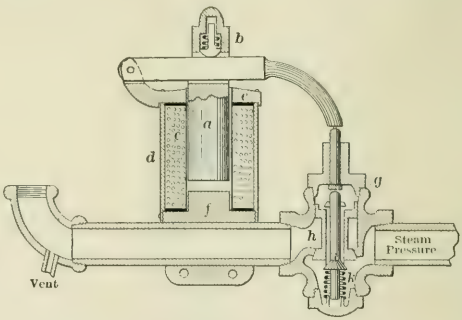
For charcoal, coke, wood alcohol, acids, etc., the Buffalo Forge Company build fans with cast iron shells and copper wheels, or in the larger sizes built of copper and brass throughout. Special fans of different construction are made to order; for instance, fans built entirely of aluminium are used for handling nitric acid fumes, and for certain sulphuric acid processes fans are of heavy cast iron throughout; in other cases composed of a mixture of lead and antimony.

Extensive developments have recently been made in the use of the waste gases from blast furnaces for power purposes. When used in gas engines, these gases will develop from five to six times as much power as when burned in the boilers. This opens a tremendous field for power development, and even bids fair to make the blast furnace as important as a producer of power as it is now as a producer of pig iron. One main obstacle which has hitherto prevented such a use of the blast furnace gases in gas engines, was the fact that they contain dust which rapidly destroys the surfaces of cylinders and pistons. To eliminate this dust the Buffalo Forge Company have developed huge gas-cleaning fans, and at the present time have batteries of fans in operation at a single steel plant which serves a total of 26,000 hp. of gas engines.

The special applications of fans for electrochemical industries are very common, as a visit through the works in all the electrochemical concerns at Niagara Falls will demonstrate.

ELECTRICALLY OPERATED STEAM OR AIR WHISTLE.

The problem of successfully operating a whistle for signal or other purposes by electricity has been developed by the Electrical Appliance Company of Cincinnati, Ohio. The adjoining illustration shows the standard type for all ordinary pressures of steam. This device operates any whistle up to



ELECTRICALLY OPERATED STEAM WHISTLE.

three inches diameter at 150 pounds steam pressure and when provided with a larger valve will operate a six-inch whistle at the same pressure. It may be placed either indoors or out, and at any required distance from the operating key.

In the illustration, *a* is an iron plunger, *b* a spring to raise this plunger above lever, *c* a magnet winding, *d* an iron shell, *e* the iron cap of the magnet, *f* the iron base of the magnet, *g* expansion chamber, *h* large valve seat, *i* small valve seat, and *k* spring to close the valves.

A special feature of this device is the fact that it may be operated either by direct or alternating current. Since the actuating solenoid must evidently be operated with direct current, it is necessary to convert the alternating current of the supply circuit into direct current for actuating the solenoid. This is acomplished by means of the Churcher electrolytic rectifier which was described on page 76 of our February issue.

The electrically-operated whistle should be useful in many large plants, such as steel mills, ship yards, lumber yards, etc., while various local uses will readily suggest themselves to steam engineers.

INDUSTRIAL NOTES

Gold Refining.—With reference to the articles of Dr. E. Wohlwill on gold refining published in our June and July issues, we are informed that Dr. Franz Meyer, 52 Broadway, New York City, is the representative of Dr. Wohlwill for his gold refining process in the United States and Canada.

Instruments and Apparatus for Laboratories and Schools.—We have received from the *Laboratory and School Supply Co.*, 20 to 24 East Twentieth Street, New York City, a pamphlet on "Kryptol," a new heating substance for electric furnaces. It is a granulated resistance material which takes the place of the heating wire in electric heating apparatus. It is either filled into the heating apparatus or spread out on clay or enamel plates. According to the thickness of the layer of kryptol and intensity of the current, the temperature can be changed at will, so that it is possible to produce different temperatures at different points of the same surface. The pamphlet describes various electric furnaces and heating apparatus adapted for the use of Kryptol. The same company have sent us a list of the very numerous apparatus exhibited by them at the World's Fair in St. Louis. They are to be found in the exhibit of the German Government in the Electricity Building (educational laboratory), Palace of Agriculture (chemical laboratory for an agricultural experiment station, and in the German Food Exhibition). Those apparatus which are of special interest to our readers will be described in one of our next issues in connection with the Exposition reports.

The International Acheson Graphite Company, of Niagara Falls, have broken ground for their new addition to their plant. The new buildings will measure 100 feet by 155 feet and will be constructed of steel. In this way the present capacity of the works will be doubled. Across Buffalo Avenue there is being erected a two-story office building to be occupied by the Acheson Graphite Co. and the Siloxicon Brick Co., which latter company will also shortly erect a factory.

Messrs. Geo. G. Blackwell, Sons & Co., Ltd., Liverpool, England, have sent us a copy of a new edition of their pamphlet on specialties for basic steel furnaces and refractory linings for steel, copper, lead, cement, electrical, oil, gas and smelting furnaces. The pamphlet gives interesting notes on fluorspar, ferro-phosphorous, magnesite, bricks, chrome firebricks and bauxite bricks.

Weston Instrument Patent Litigation.—Another decision has recently been rendered in the litigation on the Weston patents for electric measuring instruments. The suit was brought against the Whitney Electrical Instrument Co., on a patent issued to Edward Weston, dated November 6, 1888 (No. 392,387), and the decision was that the patent is infringed by an instrument made by the defendant. The court states that the parts of the defendant's instrument look quite different from the corresponding parts of the patent in suit, but notwithstanding these differences in form they are there in the instrument and do the same things in substantially the same way. The great thing to be done appears to have been to get the movable coil in its diamagnetic frame into a permanent magnetic field, compactly, and to carry the current to be measured from side to side through the coil; and move the coil against steady resistance to measure the current and record the measurement. The defendant's instruments have the permanent magnetic field provided by a magnet and a core of different and perhaps better shapes in some respects, but permitting movement of the frame in an arc of a circle to carry a pointer moving over a scale to indicate the measurement of the current. If these changes of form are even patentable improvements, the defendants have taken and used the invention of the patent in making and using their improvements. It was held that the differences do not, any or all of them, amount to doing the same thing in different ways, but leave operative parts doing the same things in the same way. A motion for a preliminary injunction was granted. The opinion is endorsed by Judge Lacombe as follows: "Upon re-examination of the record I concur in the opinion above expressed by Judge Wheeler."

The Perth Amboy Chemical Works, of Perth Amboy, N. J., have issued a pamphlet on the use of formaldehyde as a disinfectant, deodorizer, insecticide, antiseptic, preservative, in breweries and tanneries, in photography, in paint and glue shops, in the paper industry, in agriculture, therapeutics, etc. The pamphlet is concluded by a description of a convenient method of analyzing formaldehyde.

Messrs. Archibald Constable & Co., Ltd., of 2 Whitehall Gardens, S. W. London, announce the removal of their offices to 16 James Street, Haymarket, London.

Tangential Water Wheels.—The Abner Doble Co., of San Francisco, Cal., have sent us a neatly illustrated pamphlet on various details of construction of tangential water-wheels to operate under high heads of water. This company has made a specialty of producing large units of high economy, close regulation and absolute reliability in service.

We have received from the Deutsche Steinzeugwaaren Fabrik for canalization and chemical industries in Friedrichsfeld, Baden, a neat pamphlet containing a description of the development and equipment of their works and output. The New York representative of this company is Frederick Bertuch & Co., 5 Beekman Street. The pamphlet was distributed on the occasion of a recent visit of the Society of German Chemists to the works. The plant now employs 700 workingmen.

PERSONAL.

Dr. J. W. Richards, of Lehigh University, sailed on July 6, on the steamer "United States" of the Scandinavian-American line to spend two months on the coast of Norway.

Mr. Carl Hambuechen, who is well known to the electrochemical fraternity by the excellent work which he has done as Prof. Burgess' coworker at the University of Wisconsin, is now connected with the Pittsburgh Reduction Co., at East St. Louis, Ill.

Dr. Schuyler Skaats Wheeler, president of Crocker-Wheeler Company, sailed on July 13, with Mrs. Wheeler, on the White Star Liner "Baltic." On the pier, he said that he had planned a coaching trip in England; but early this spring Dr. Wheeler went on an automobile tour through the South of France and returned with the American patent rights of Brown, Boveri & Cie., of Baden, Switzerland. Dr. Wheeler's friends and rivals are beginning to take a lively interest in his holiday trips.

The University of Wisconsin, at its recent jubilee celebration, conferred the degree of LL. D. to Prof. Edgar F. Smith, of the University of Pennsylvania. President Van Hise addressed him as follows: "Edgar Fahs Smith—for pioneer work in the electrolytic separation of metals; for valuable researches upon the compounds of tungsten, molybdenum and uranium; for the training of a large number of scholars devoted to the advancement of the science of chemistry, this university confers upon you the degree of doctor of laws."

DIGEST OF U. S. PATENTS

Prior to July, 1902.

Compiled by Byrnes & Townsend,
Patent Lawyers,
National Union Building, Washington, D. C.

Production of Sodium from Molten Electrolytes.

(*Continued from page 296.*)

464,097, December 1, 1891, Ludwig Grabau, Hanover, Germany.

Lowers the melting point of a sodium chloride bath, to

prevent recombinations, by employing a mixture of potassium and sodium chlorides in equi-molecular proportions, and a chloride of an alkaline earth metal, preferably strontium, in the proportion of one molecule to three molecules of the alkali metal chlorides. The fusion temperature is thus lowered from a bright to a dull red.

The product contains 3 per cent of potassium, which may be removed from the sodium by melting the alloy under petroleum and injecting sufficient air to oxidize the potassium.

517,001, March 20, 1894, J. D. Darling, Philadelphia, Pa.

Electrolyzes fused alkali metal nitrates, the first sodium reducing the nitrate at the cathode to nitrate and oxide, which dissolves in the nitrite. The nitrate is fused before electrolyzing and may be heated to a high temperature to drive off as much oxygen as possible to prevent attack on the anode. Employs a cathode vessel of aluminium, with a partition of aluminium extending nearly to its bottom. The anodes are of carbon or platinum, each surrounded by a sleeve of aluminium having inwardly and upwardly extending perforations to retain the anions, nitrogen dioxide and oxygen, which are conducted through Woullf bottles holding water, to produce nitric acid. May maintain a partial vacuum in the bottles and thus dispense with the aluminium sleeves. A feed hopper extends into the cell, being sealed at the bottom by the electrolyte.

531,235, December 18, 1894, C. T. J. Vautin, London, England.

Electrolyzes sodium or potassium carbonates or chlorides, to which may be added calcium or strontium chloride to lower the melting point. The vessel may be the hearth of a reverberatory furnace. The cathode is molten lead, beneath the electrolyte. Carbon anodes, surrounded by fire-clay sleeves to withdraw the chlorine, extend through the furnace roof. A horizontal passage extending from the bottom of the hearth opens into the bottom of an oxidizing vessel, wherein a jet of steam is thrown upon the alloy, converting the alkali metal into caustic, which may be ladled or tapped off. Fresh quantities of the alkali metal continuously diffuse from the cathode into the oxidizing vessel, as removed by the steam.

According to a modification, a lined crucible serves as the cell.

541,465, June 25, 1895, C. T. J. Vautin, London, England.

Electrolyzes alkali or alkaline earth metal chlorides on a cathode of molten lead or tin. The vessel may be an iron crucible, the sides of which are lined with magnesia, or the hearth of a reverberatory furnace. An outlet pipe for the alloy leads from the cell and is surrounded by a coil of pipe carrying water. A portion of the alloy is thus chilled in the outlet to constitute a plug, which melts out when the flow of water is stopped. The alloy may be cast into blocks by running it through a jet of reducing gas into a mold; or it may be discharged into a retort lined with magnesia or carbon and the alkali metal distilled off and condensed, the heating means being a carbon resistance rod in a tube passing horizontally through the retort.

542,057, July 2, 1895, L. P. Hulin, Modane, France.

Electrolyzes molten haloids of alkali or alkaline earth metals, on a cathode of molten lead or tin. The vessel is of iron, the sides having an insulating lining. There are four anodes: one of carbon; two of iron in shunt with a resistance and ammeter, purpose not stated; and a fourth of an alloying metal which may be the same metal as the cathode, in shunt with another resistance and ammeter. This metal of the fourth anode, if molten at the temperature of the cell, may be held in a carbon pan carried by a tubular carbon stem serving as a feed inlet. Less fusible metals, such as manganese and chromium, may be held in a carbon pan in granular form; or pieces containing their oxides and carbon may be supported in a carbon pan; or a mixture of their oxides and carbon may be formed into a stick anode. The anode metal dissolves and is redeposited simultaneously with the light metal, the proportions being determined by the amount of current supplied to the various anodes, the deposit being mostly of light metal. The soluble metal anodes permit the use of a lower e. m. f. and may be supplied with current from a separate dynamo; or current may be fed to them intermittently. May produce alloys with two or more heavy metals, using a molten bath containing haloids of both metals, with anodes of each or an anode consisting of an alloy of both. A feed inlet for the salt opens into the cell below the surface of the electrolyte. The molten cathode is continuously agitated by an iron stirrer.

544,153, August 6, 1895, W. Borchers, Duisburg, Germany.

Electrolyzes molten sodium chloride in a conductive or non-conductive vessel having a conical bottom, the inner face of which consists of a series of horizontal, annular grooves. The grooves are filled with molten lead, constituting the cathode. Lead is continuously supplied to the top groove and the alloy is withdrawn from the bottom. The body of the vessel is surrounded by a water-jacket, which cools a lining of the solidified salt on the inner wall.

The anode is a piece of charcoal or metal extending through the vessel-cover.

589,523, September 7, 1897, J. Boelsterli, Neuhausen, Switzerland.

Electrolyzes alkali metal compounds in an iron crucible. The anode is a vertical ring, surrounded by an iron sheath to retain and carry off the oxygen. The cathodes are depending metal rods, arranged in a ring around the anode and adjustably supported by radial arms extending from a sleeve on the anode stem. The lower end of each rod is rounded and just dips below the surface of the electrolyte. These ends gather the globules of metal that float on the surface, and they are then removed by a skimmer. The skimmings are placed in a separating vessel to permit any portions of the electrolyte therein to settle out.

590,826, September 28, 1897, J. D. Darling, Philadelphia, Pa.

Electrolyzes molten alkali or alkaline earth metal hydroxides, haloids, nitrates or sulphates, in a diaphragm cell. The diaphragm consists of concentric cylindrical cups of perforated sheet iron, with an intermediate space which is filled with vitrified magnesia, in fragments which will pass through a 20-mush, but not through a 30-mesh sieve. A ring of cement is filled in at the top.

Other earthy oxides or mixtures, *e. g.*, of calcium or barium, may be used.

607,506, July 19, 1898, Paul Danckwardt, New York, N. Y.

Electrolyzes molten alkali metal chlorides. The cell is a rectangular chamber with anode and cathode compartments partially separated by a depending water-cooled partition. The walls of the anode compartment consist of water-jackets lined with tile; those of the cathode compartment, of firebrick with a sheet iron lining serving as cathode. Several parallel iron strips extend from the bottom of the iron lining into the upper hotter portion of the electrolyte, to prevent it from cooling on the bottom. The bottom of the cell is of firebrick, with embedded water pipes to cool it. The anode compartment has a cover with inlet and gas outlet. Carbon anodes extend through one side of the anode compartment and nearly to the cathode compartment. Heat is supplied by a blow-pipe passing through one end of the anode compartment, above the electrolyte; or a layer of charcoal may be supported on the anolyte and burned by an air-blast. The alkali metal floats and is continuously run off from the cathode

(*To be continued.*)

Electrochemical Industry

VOL. II. NEW YORK, SEPTEMBER, 1904. NO. 9.

Electrochemical Industry

Published on the first of each month by the
ELECTROCHEMICAL PUBLISHING COMPANY,
[Incorporated.]
114-118 LIBERTY STREET, NEW YORK.

J. W. RICHARDS, PH. D. ..... *President.*
E. F. ROEBER, PH. D. ..... *Editor.*

Telephone Call: 7607 Cortlandt.

Subscription Price: $2 per year, postpaid to any part of the world. Single copies 25 cents.

ADVERTISING RATES GIVEN ON APPLICATION.

Copyrighted, 1904, by the Electrochemical Publishing Co.

Entered as Second-Class Matter, June, 1903, at the Post-Office at New York, N. Y., under the Act of Congress, March 3, 1879.

CONTENTS.

Editorial 335
American Electrochemical Society 338
Society of Chemical Industry 338
Some Notes on the Uses of Electrolytic Chlorine. By F. Winteler. 339
Some First Principles of Electric Resistance Furnaces. By F. A. J. FitzGerald 342
Uses of Acheson Graphite in Metallurgical Research. By W. McA. Johnson 345
Biographical Sketch of Wm. H. Nichols 347
Sulphuric Acid by the Contact Process 347
Manufacture of Ferro-Alloys in the Electric Furnace. By G. P. Scholl 349
The Electric Properties of the Films that Form on Aluminium Anodes. By W. R. Mott 352
Laboratory Course in Industrial Chemistry 355
Electrolytic Production of Zinc and Lead from Complex Sulphide Ores. By C. W. Burleigh 355
Manufacture of Sodium by the Becker Process. By C. F. Carrier, Jr. 357
German Bunsen Society Meeting. By H. Danneel 360
Analysis of Current Electrochemical Patents. By G. P. Scholl 364
Recent Metallurgical Patents 366
Synopsis of Articles in Other Journals 368
Correspondence: Lead Peroxide Anodes for the Cyanide Process. By E. M. Hamilton 372
Book Reviews: G. T. Hanchett, Alternating Currents 373
F. G. Baum, The Alternating-Current Transformer 373
International Electrical Congress 373
St. Louis Exposition 374
Personal 384
Obituary 384
Digest of U. S. Patents, Prior to July, 1902. By Byrnes & Townsend. (Electrolysis of Fused Sodium Salts) 384

THE INTERNATIONAL ELECTRICAL CONGRESS.

It should be a matter of congratulation to the whole electrochemical fraternity that Section C (Electrochemistry) will be one of the strongest sections of the St. Louis International Electrical Congress. The programme of this section is an excellent one and contains papers by the foremost representatives of electrochemical science and art. Moreover, the steadily increasing influence of electrochemistry manifests itself occasionally in the programme of the other sections. It was an unselfish but a very wise policy of the officers of the American Electrochemical Society to decide to hold only one independent session and otherwise to further with all means the success of the Congress. There can be no doubt that the result will be most gratifying to all who will attend the Congress and will further the common cause in which electrochemical engineers and scientists are alike enlisted.

USES OF ELECTROLYTIC CHLORINE.

In the production of caustic soda and bleaching powder by electrolysis of common salt, electrolytic methods have achieved a most significant success. In this field electrochemistry came into direct competition with one of the best established and technically the best developed of the chemical industries, and electrochemical methods came out victorious. Moreover the great variety of possible methods at the disposal of the electrochemist is emphasized by the fact that the principal technical problem in the present case—to keep the anodic chlorine separated from the NaOH formed at the cathode—has been solved in various essentially different ways: first, by absorbing the discharged sodium ions by the cathode and thus removing them out of the sphere of chlorine, either by the use of a cathode of mercury (Castner-Keller) or of fused lead (Acker); secondly, by separating the anode compartment from the cathode compartment by means of a diaphragm; thirdly, by keeping the anolyte separated from the catholyte by gravity, making use of their different specific gravities (Glocken process). However, this success of electrochemistry in the manufacture of caustic soda and chloride of lime has been rather an engineering success than an industrial success; that means, while all difficulties in the methods of manufacture were successfully overcome, the financial result has not been correspondingly encouraging. The trouble lies on the chlorine end of the business, there being very little profit in making bleaching powder in the present state of the market. If all the electrolytic chlorine is used for making bleaching powder, the output of bleaching powder is chemically equivalent to the output of caustic soda—but no corresponding industrial law rules the demand for both products. Possibly an agreement between the various manufacturers as to the selling price of bleaching powder might temporarily help matters. But a radical remedy would be the resolution of our manufac-

turers to make only as much bleaching powder as they can sell at a good profit, and to utilize the excess of chlorine for making other valuable products. In this respect the article of Dr. F. Winteler, published in our present issue, is highly suggestive and should give valuable hints to our manufacturers, since the majority of the products described by Dr. Winteler were made by him on an industrial scale from electrolytic chlorine. Especially the possibility of making organic compounds seems interesting. Here we have an opening for a natural growth of industrial organic chemistry on American soil. American electrochemists have always distinguished themselves by enterprise and power and spunk. It would not be surprising if the commercial troubles which our manufacturers have with their electrolytic chlorine would lead to important industrial advances in the line of organic chemistry in this country. There is no reason whatever that the United States should be an importer of organic compounds all the time.

ELECTRIC FURNACE DESIGN.

The first electric furnaces in which the fundamental pioneer work was done, were necessarily of rather crude design; but they were sufficient to bring out forcibly one fundamental point, namely, that it is possible to produce by means of the electric furnace very high temperatures not attainable by other means, and thus to start new reactions and obtain new compounds. Later on electric furnace design passed through an extended experimental and theoretical development, and is now based on exact scientific principles, like the design of dynamos or steam engines. To operate an electric furnace process industrially to the best advantage, the furnace must be so designed that the rather costly electrical heat is utilized and concentrated at exactly the point where it is needed, and that the temperature is under the absolute control of the operator. The details of electric furnace design are at present the property of a relatively small number of electrochemical inventors and engineers who have worked them out, and it is quite natural that they are not disposed to give them to the public. While it is thus possible that the day is far off when all details of electric furnace design will become public property of the electrochemical fraternity, yet there is no reason that the principles of the design and manipulation of electric furnaces should not be now within the reach of anybody who wants to work in this line. But information in this direction has so far been rather scattered and inaccessible.

While the first electric furnace experiments were made with arc furnaces, the tendency has, in recent years, been to develop the electric resistance furnace, on account of the great ease with which the temperature can be controlled in the same. A convenient special type is that in which an electric current is passed through a resistance material and the electrical energy converted into heat which does useful work. We are glad to announce that we will publish a series of articles on the construction and manipulation of this type of furnace, by Mr. F. A. J. FitzGerald, who has been intimately connected with the development of this type for many years. The intention is to discuss the principles on which furnaces of this kind are designed, and then to go into details of construction, and to give hints how experiments may be carried out on a small scale without costly or complicated apparatus. We have no doubt that this serial will be welcome to many of our readers, and will help to assist the useful growth of industries which may advantageously use this type of furnace. The first article of Mr. FitzGerald's serial is published in our present issue and deals with some first principles. We like to call attention to one point forcibly brought out by Mr. FitzGerald. It is that the heat generated at a point depends on the watts per unit of volume, while it is ordinary but objectionable practice to give the current density in amperes per unit of cross-section. This latter figure, however, does not determine the temperature unequivocally, since the conductivity of the resistance material is to be taken into account, and even if the same resistance material is used throughout the furnace, the conductivity may vary according to the greater or smaller degree in which the resistance material is compressed at different points of the furnace.

CONTACT PROCESSES AND ELECTROLYSIS.

Catalytic action has long been known. We designate by this name all phenomena in which a substance (catalyzer) must necessarily be present if a certain reaction is to take place, although the catalyzer apparently does not participate in the reaction. Since it seems to act simply in virtue of its contact with the reacting substances, we speak of a contact process. A satisfactory explanation of catalytic action has not yet been found, nor does it seem probable that the same explanation will apply to all different kinds of catalytic action. But we are sufficiently acquainted with the catalytic property of various substances to utilize it in practice. In the special case of the manufacture of sulphuric acid, the introduction of the contact process has nearly brought about an industrial revolution. An interesting article on the contact process for making sulphuric acid will be found on another page of this issue. Here we wish to point out briefly for what purpose catalytic action might be utilized in electrolysis. If at an electrode a number of reactions are possible, these reactions will start one after the other, when the voltage is gradually raised, since each reaction requires a distinct minimum voltage, proportional to the free energy of the reaction. If the voltage is sufficiently high, several electrochemical reactions will simultaneously occur. Of course, what we may call the speed of the total chemical reaction (measured in the number of all gramequivalents, together undergoing reduction or oxidation at the two electrodes, per second) is directly given by the current in amperes, according to Faraday's law. But this law does not determine to what extent the different single possible reactions will take place. It is at this point that calatyzers might prove useful, as may best be seen from the point of view of Ostwald, who considers as the characteristic feature of a catalyzer its influence upon the speed of a reaction. There are "positive" catalyzers which increase the speed of a reaction, like platinum in the sulphuric acid contact process, and there are "negative" catalyzers, which tend to retard the speed of a reaction. By judiciously using either positive or negative catalyzers in con-

nection with the electrolytic reaction at an electrode, it would appear to be possible to force the current to select the one desired reaction out of a number of possible reactions. In fact, working on this basis, Ostwald and Luther have done elaborate and extended laboratory research work, so that Prof. Ostwald's paper to be presented at the St. Louis Congress, on this subject, should be expected to contain interesting information. It is by no means impossible that catalytic action may play an important part in future in industrial electrolytic processes.

RECENT DEVELOPMENTS IN ZINC METALLURGY.

Many attempts have been made to accomplish improvements in the metallurgical working of zinc ores, by applying electrochemical methods. Electrolysis has chiefly been resorted to, but no electrolytic method has been a commercial success on a large scale in the past, though most of the engineering difficulties were cleverly overcome. A special problem of considerable industrial importance is the production of zinc from complex sulphide ores. Two new electrolytic processes attempting to solve this problem have recently been tried on a larger scale. The one is Swinburne and Ashcroft's "chlorine smelting" process, which was described at some length in our August issue of last year. The scheme is to first treat the ores with hot chlorine in order to change the sulphides into chlorides, then to treat chemically the mixed chlorides by substitution in order to replace all other metals by zinc, finally to electrolyze the fused zinc chloride. Recent developments of this process will be dealt with in a paper to be presented by Mr. Swinburne before the Electrical Congress in St. Louis. A second process which has recently been tried on a larger scale is that of Mr. Burleigh, who describes it in an interesting article published in our present issue. After preliminary metallurgical treatment, he dissolves the metallic contents of the ore in a "soda solution" and first wins lead and then zinc by electrolysis. Mr. Burleigh appears to have successfully overcome all main difficulties, so that further and more detailed information concerning some phases of the process which are dealt with somewhat briefly in his present article are to be awaited with interest.

Little has been done commercially with the electric furnace in the zinc industry, though the two brothers Cowles, in their early experiments, used the electric furnace for zinc distillation. In recent years de Laval is reported to have designed and to operate an electric arc furnace (somewhat of the type of the Moissan furnace) for zinc distillation on a larger experimental scale in Sweden. It would appear that the electric furnace should have distinct advantages for this purpose. In our present commercial zinc distillation plants, with their expensive retorts and with the essential necessity of applying external heat, the fuel really consumed is greatly in excess over that theoretically required. In the electric furnace we can generate and concentrate the heat at the spot where it is needed. But if we consider that heat generated from electrical energy is rather expensive, it will be clear that if electric furnace methods shall succeed in the zinc industries, the furnace must be carefully designed with due respect to all special requirements of zinc distillation.

In the meantime numerous experimenters continue trying to solve the problem of smelting zinc ores in the blast furnace. It has long been known that the process is not at all theoretically impossible, and attention has been called to the fact that occasionally metallic zinc is formed as a by-product in blast furnace plants for the treatment of zinciferous iron and lead ores. But whenever the blast furnace has been applied directly for zinc production, the zinc has not been obtained in liquid form, but in form of a powder of zinc, mixed or not with zinc oxide. The reason is that when zinc oxide is reduced in the blast furnace, the vapor is always diluted with the nitrogen of the air (which will cause the zinc to be obtained in dust form) and with the combustion products of the fuel and unconsumed air (which will cause immediate reoxidation). By an interesting method described in this issue under "Recent Metallurgical Patents," Dr. O. Nagel proposes to carry out the distillation of zinc from ore, mixed with coal, in the atmosphere of natural gas, which acts as a reducing agent. Dr. Nagel had formerly proposed to use water gas, preferably preheated before introduced into the furnace. Coal is mixed with the ore, so that any gases shall be reduced which may become oxidized by the reduction of zinc oxide. The zinc vapor may then be obtained in such a concentrated condition as to condense to spelter. The main point in Dr. Nagel's new patent is that coal gas and natural gas are equal and sometimes superior to water gas. It will thus be seen that there is at present a great activity among zinc metallurgists and that the tendency in general is not to look for improvement of details of the present metallurgical methods, but rather to open new avenues of progress.

EFFECT OF ALTERNATING-CURRENT FREQUENCY IN ELECTROCHEMICAL WORK.

If it is intended to produce a chemical effect by sending an alternating-current discharge through a gas, it is quite evident that the frequency must be high enough, and it seems reasonable to expect the best results if the frequency is between certain limits. For instance, in a patent recorded in our April issue, Kowalski reports that for the production of nitric acid from air the best frequency is between 6000 and 10,000 alternations per second. If an alternating current should be used for producing electrolytic decomposition, it is also quite evident that the frequency will have a decided effect. In this case it should not be too high, since the lower the frequency, the greater is the chance for the products of electrolytic action, obtained during one-half wave of the alternating current, to be removed from contact with the electrodes so that they are not changed back into the original state during the next half wave. In electric furnace processes it has, up to the present, always been assumed that the frequency has no influence. But from a patent of W. S. Horry, abstracted in this issue, it appears that a higher frequency has a distinct beneficial effect in the production of calcium carbide. The explanation, given by Mr. Horry, seems quite reasonable. It is that the furnace charge undergoes electrolytic decomposition if the frequency is too low—and this means, of course, a diminished efficiency.

AMERICAN ELECTROCHEMICAL SOCIETY.

The meeting of the American Electrochemical Society will be held in St. Louis on the 13th, 15th and 16th of September. On the 13th and 15th joint sessions will be held with Section C (Electrochemistry) of the International Electrical Congress, while on the 16th an independent meeting will be held which is designated as a joint meeting with the Bunsen and Faraday Societies, and to which the members of the Congress will be invited.

A local committee of the Electrochemical Society has not been appointed, but the following St. Louis members will be glad to answer inquiries: Mr. C. D. Chasteney, De Laval Steam Turbine Co., Mining Gulch, Exposition Grounds, St. Louis; Mr. F. E. Drake, President Lanyon Zinc Co., 607 Carleton Building, St. Louis; Prof. W. E. Goldsborough, Chairman Department of Electricity, World's Fair, St. Louis; Mr. Carl Hambuechen, Pittsburg Reduction Co., East St. Louis.

The official delegate of the Bunsen Society is Dr. Hans Goldschmidt of Essen-Ruhr, Germany, who, on request of the Congress authorities, will deliver a lecture on aluminothermics, with numerous demonstrations, at one of the evening sessions. Provisionally, the date has been fixed for Sept. 13, and as place the hall of the Westinghouse Co. will be used.

The Faraday Society will be represented by four official delegates: Prof. F. G. Bailey, Heriot-Watt College, Edinburgh; Mr. Sherard Cowper-Coles, London; Mr. J. S. MacArthur, London, and Mr. E. K. Scott, Beesfield, Farmingham, Kent.

The Electrochemical Congress papers (to be presented on Sept. 13, 14 and 15 before Section C) are printed on another page of this issue. At the session to be held on Sept. 16, Prof. F. G. Bailey, of the Faraday Society, and Dr. Hans Goldschmidt, of the Bunsen Society, are expected to read papers, the titles of which are to be announced later. There will also be presented papers by members of the Electrochemical Society, among them Prof. W. D. Bancroft on the aluminium rectifyer, and Prof. H. E. Patten on an analytical study of the deposition of aluminium from ethyl bromide solutions.

Members are requested to register at the Coliseum as soon as they arrive, on Saturday, Monday or Tuesday. Badges of the Electrochemical Society will admit members to the independent meeting on September 16th, and to the joint meetings with the Congress on the 13th and 14th, but not on the 15th, unless members of the Congress. Application for membership to the Congress (fee $5.00) will be received up to the close of the exercises on Sept. 17.

A *Dinner Rendezvous* is being arranged to be held at a popular restaurant in the World's Fair Grounds at 6.30 to 7.30, on the 13th, 14th, 15th and 16th. It will probably be at the Tyrolean Alps Restaurant at the portion of "The Pike" next to the Main Entrance, the cost not to exceed $1.50. This is in lieu of a banquet, as it is believed it will be better appreciated.

SOCIETY OF CHEMICAL INDUSTRY.

The Society of Chemical Industry will hold its annual general meeting in New York City from September 7th to 11th. This will be the first general meeting held in America, and a most elaborate programme has been arranged, a general outline of which was given in our April issue, page 148, which will be fully carried out, all arrangements having been completed. Over eighty (sixty-seven gentlemen and fourteen ladies) from abroad have already signified their intention of accepting the invitation of the New York Section of the Society of Chemical Industry, and this list is being added to from time to time, and it is hoped that the final number will be not less than 100. The expense of entertaining members from abroad while in New York, and for the cost of their transportation and sleeping accommodations on the round trip through the country is covered by subscription by the New York Section. On the round trip the following places will be visited: Philadelphia, Washington, Pittsburg, St. Louis, Chicago, Detroit, Buffalo, Niagara Falls, Boston and back to New York. For the visits of these places, a most elaborate programme has been arranged. The members participating in the trip will attend the congresses for Inorganic and Organic Chemistry, and for Technical, Physical and Physiological Chemistry in St. Louis on September 21 and 22.

The programme for the meeting in New York is as follows:

Wednesday, September 7th, at 9 p. m., at the Chemists' Club: Informal reception.

Thursday, September 8th, at Columbia University: 10 a. m., council meeting. 10.30 a. m., general meeting; address by Sir William Ramsay. 1.00 p. m., informal luncheon at a place to be announced later. 2.30 p. m., seeing New York by stages and automobiles. 7.30 p. m., annual dinner.

Friday, September 9th: Visits to manufacturing establishments. 8.30 p. m., roof garden entertainment.

Saturday, September 10th: Visits to manufacturing establishments. 8.30 p. m., smoker at one of the New York clubs.

Sunday, September 11th: Excursion by steamer around New York, the Sound and up the Hudson.

Following is a list of manufacturing establishments and places of interest in and around New York to which visits will be made. An asterisk means that ladies are invited:

Westinghouse, Church, Kerr & Co., Power-house for Pennsylvania Railroad at Long Island City.

Consolidated Gas Co., Gas Works at Ravenswood, L. I. (Limited to 25.)

New York Edison Co., Waterside Station, Thirty-eighth to Thirty-ninth Streets and East River. (Limited to 25.)

Schwarzschild & Sulzberger Co., Abattoir, Forty-fifth Street and First Avenue.

Nichols Chemical Co., Copper Refinery at Laurel Hill. (For English members and invited guests only. Limited to 75.)

*Carl H. Schultz, Mineral Water Manufacturing, 440 First Avenue, New York City. (Limited to 50.)

New Jersey Zinc Co., Spiegel Furnace, Hackensack Meadow.

Ehret's Brewery, Ninety-second Street, near Third Avenue, New York City.

Ruppert's Brewery, Ninety-second Street and Third Avenue, New York City.

Central Brewing Co., Sixty-eighth Street and East River, New York City.

Pacific Coast Borax Co., Factory at Bayonne, N. J.

*Tiffany & Co., Jewels and Jewel Cutting and Setting.

*Metropolitan Museum of Art, Fifth Avenue and Eighty-second Street, New York City, Bishop Collection of Jade; Morgan Collection of Porcelains; Gold Room, etc. This will be followed by a luncheon at the Casino in Central Park, for which a charge of $1.50 will be made to American and Canadian members.

*American Museum of Natural History, Columbus Avenue and Seventy-seventh Street, New York City, Gem Room, Bement Collection of Minerals, etc.

Tartar Chemical Co., Ninth Street and Gowanus Canal, Brooklyn.

Tide Water Oil Co., Bayonne, N. J.

Balbach Smelting & Refining Co., 73 Passaic Avenue, Newark, N. J.

Murphy Varnish Co., McWhorter and Chestnut Streets, Newark, N. J.

F. W. Devoe & C. T. Raynolds Co. (Paints, etc.), 565 Smith Street, Brooklyn.

John W. Masury & Sons (Paints, etc.), 50 Jay Street, Brooklyn.

B. Moore Co. (Paints, etc.), 262 Water Street, Brooklyn.

The Congress of Chemistry in St. Louis will be part of the International Congress of Arts and Science, and will be subdivided into the four sections for inorganic, organic, physical and physiological chemistry.

SOME NOTES ON THE USES OF ELECTROLYTIC CHLORINE.

By F. Winteler, Ph. D.

The most convenient method of utilizing electrolytic chlorine is, without any doubt, the manufacture of bleaching powder. Up to the present time all plants which make caustic potash or caustic soda by electrolysis, have also made bleaching powder.

Years ago, however, the danger was already recognized that in time an overproduction of chloride of lime would result, and this has now become a fact. As a result of this overproduction the price of bleaching powder has gone down to such an extent that there is scarcely much profit in its manfacture. Nevertheless, the works continue to produce chloride of lime for the reason that it is not feasible to let the chlorine gas escape into the air, while up to the present the manufacture of other products has been somewhat out of the line of work of these plants.

In the present state of affairs, however, it will be in the interest of manufacturers to consider the production of other compounds from their chlorine, since that plant which makes from chlorine the most valuable compounds, will also occupy the strongest position in the caustic alkali market.

Bleaching Powder.

A few remarks may be made on the manufacture of chloride of lime. Its production is convenient to factories, especially for the reason that chlorine passes from the electrolytic cells under atmospheric pressure. Plants which are correctly designed are even careful to produce a lower pressure in the cells. For this purpose the cells are placed on the second floor of the building, and the chloride of lime chambers, some four meters deeper, on the first floor. If for any reason a cell should get a leak, the chlorine gas which, on account of its higher specific gravity, passes downwards, will suck air with it, and there will be no smell of chlorine in the cell room. A mixture of chlorine with air is in no way detrimental to the manufacture of chloride of lime—on the contrary, it is advantageous.

Chloride of lime thus produced will contain 36 per cent of active chlorine if the following conditions are observed.

(1) The chlorine should be as dry as possible.

(2) The calcium hydroxide should be as dry as possible.

(3) The temperature during the reaction of the chlorine with the calcium hydroxide should not be higher than 35° C. This is easily accomplished by allowing the chlorine to suck in about 50 per cent of air before entering the calcium hydroxide chambers.

(4) No excess of chlorine should be introduced into the calcium hydroxide chambers. The introduction of chlorine should be stopped as soon as a test shows a content of 33 to 34 per cent of active chlorine. The chlorine gas, which is still in the chamber is then slowly absorbed and the content rises to 36 per cent. If more chlorine would be introduced in the meantime, the content of active chlorine would decrease, since the hypochlorite which already has been formed would be changed to chlorate by the chlorine, introduced in excess, even at a low temperature.

If, instead of calcium hydroxide chambers mechanical apparatus are used, the supply of fresh calcium hydroxide is so regulated that the analysis of the chloride of lime, taken from the bottom, just shows the correct content.

A content of carbonic acid in chlorine is not detrimental to the manufacture of chloride of lime, as long as the gas and calcium hydroxide are dry.

Detinning of Tinned Iron Scrap.

With respect to the manufacture of other products by means of electrolytic chlorine, it would appear that the detinning of tinned iron scrap should be specially advantageous in the United States. The manufacture of tin plate cans, containing corned beef, condensed milk and all kinds of preserves, yields an enormous quantity of tinned iron scrap. Such scrap is also obtained from many other sources. One hundred kilograms of tinned sheet iron contain 2 to 3 kg. of tin; the scrap from tin cans contains somewhat more tin, on account of the solder.

If well-dried chlorine is passed at a temperature of 40° to 50° C. over such tin scrap, the tin is changed into liquid fuming tin tetrachloride, $SnCl_4$. This drops off and is collected in bottles. If the necessary quantity of water and ammonium chloride (NH_4Cl) is added, one gets "pink salt" ($SnCl_4 + 2NH_4Cl$) which is extensively used in cotton printing and silk dyeing (to make the silk ware heavier). From 1000 kg. tinned iron scrap about 40 to 50 kg. of tin tetrachloride are obtained.

It is interesting to note that the iron on which the tin was plated is not attacked in any way by dry chlorine at the temperature mentioned. Ferric chlorides is formed only at a temperature above 100° C.

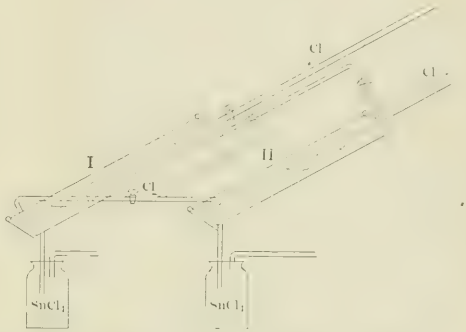


FIG. 1. PRODUCTION OF TIN TETRACHLORIDE.

The process is carried out, as shown in Fig. 1, by filling the scrap from above into inclined iron tubes which must be absolutely dry. Two such tubes are connected in series and chlorine is passed through the same until no longer tin tetrachloride drops off from the first tube. Then air is blown through until all the chlorine has passed out of the first tube. The chlorine gas is now supplied to the second tube, while the first tube is emptied and refilled to be used now as second tube, and so on.

The pure iron thus obtained is melted in the Martin furnace, or may be usefully employed, especially in the United States, for obtaining cement copper from copper solutions. While tin scrap is useless for any other purpose, this process yields both valuable tin tetrachloride and valuable pure iron.

Tin tetrachloride, as obtained by the above process, may also be treated with water and afterwards with metallic zinc; this results in the precipitation of metallic tin and formation of zinc chloride. The former is melted, while the zinc chloride is used for impregnating wooden telegraph poles, railway ties, etc.

Chloride of Sulphur.

Another compound which can be obtained from electrolytic chlorine is disulphur dichloride (sulphur monochloride), S_2Cl_2. It is used in the rubber industry in large quantities for vulcanizing India rubber.

In handbooks on chemistry it is stated that sulphur chloride is produced by passing chlorine through molten sulphur. The compound, however, may also be obtained simply by filling pieces of sulphur into a lead vessel and passing, at ordinary temperature, chlorine upwards through the vessel. An apparatus which has proven useful for the manufacture on a commercial scale is shown in Fig. 2.

It is entirely made of lead and consists of two containers which are filled with pieces of sulphur of rough surface, and through which chlorine is passed. The sulphur rests on a screen with large meshes. Below it, another screen is provided with smaller meshes, for catching any small pieces of sulphur falling down. The tubes below are protected by lead caps to prevent them from being clogged up by any solid matter falling down. Below the two sulphur containers, the vessel is provided for collecting the chloride of sulphur. It is so arranged that it may be easily emptied by compressed air. To take out smaller quantities without compressed air, a spigot is provided at the bottom.

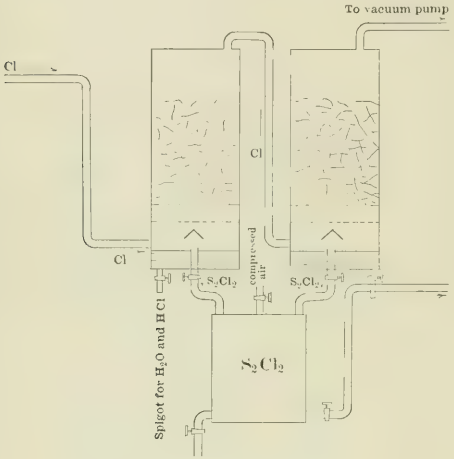


FIG. 2.—PRODUCTION OF S_2Cl_2.

If the chlorine gas is not absolutely dry, some hydrochloric acid is formed in time on the bottom of the sulphur containers; it is removed by means of small spigots in the bottom, without any loss of chloride of sulphur.

In the connecting tube between the sulphur containers and the vacuum pump, a box containing slaked slime is inserted for absorbing any chlorine passing out of the sulphur container so that the pumps should not be hurt.

For making SO_2Cl_2 the following process may be used. Sulphurous acid is brought together with chlorine in a vessel containing 50 gr. of camphor. In the beginning it is necessary to artificially heat the vessel, afterwards to cool it. The formed SO_2Cl_2 distills over at 77° C. from the camphor; at 45° some other compound distills over.

Chlorides of Phosphorus.

Phosphorus trichloride, PCl_3, and phosphorus pentachloride, PCl_5, may also be made advantageously from electrolytic chlorine. For making the trichloride, phosphorus is brought into an iron vessel, closed by a lid, as shown in Fig. 3. Through one opening in the lid, the chlorine gas is introduced, and through another opening the trichloride is led off. The latter is condensed in a water-cooled tube of copper and the liquid, which is clear like water, is collected in a stoneware vessel.

There is no necessity for artificial heating in this process. The reaction starts at ordinary temperature when the chlorine is introduced, and it is even preferable to cool with some water the vessel containing the phosphorus, since the heat of reaction is very large, and without this precaution some phosphorus may distill over.

From phosphorus trichloride it is easy to prepare pentachloride by passing more chlorine over the surface of the latter. The liquid solidifies after some time and becomes a yellow mass which represents the desired product.

In the dyestuff industries phosphorus oxychloride, $POCl_3$ is frequently used. It is obtained from pentachloride by gradually adding the proper quantity of water, according to the equation, $PCl_5 + H_2O = POCl_3 + 2HCl$. It is only necessary to take care that the addition of water is not made too

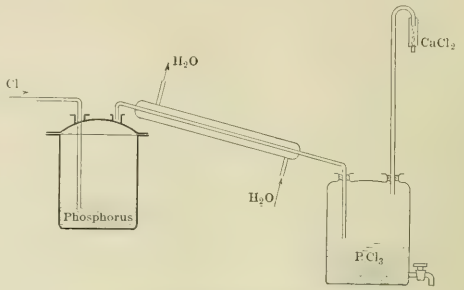


FIG. 3.—PRODUCTION OF PCl_3.

quickly, since this would result in an explosion. Finally, the escaping hydrochloric acid gas is condensed with water.

A very convenient method of making phosphorus oxychloride from pentachlorides is by means of distillation with dry orthoboric acid, according to the equation $2H_3BO_3 + 3PCl_5 = B_2O_3 + 3POCl_3 + 6HCl$. The reaction is absolutely quiet.

Peroxide of Lead.

Finely powdered lead acetate is put into a lead vessel, which can be heated with steam. Chloride of lime solution in the quantity theoretically necessary for the reaction, is then poured on it. The mixture is then heated to boil, until the vapor smells of acetic acid. The lead peroxide, thus formed, is placed on a filter and washed. 100 kg. of lead acetate give a 39 per cent paste (1 kg. paste containing 390 grams of PbO_2), this corresponds to an efficiency of 81 per cent of the theoretical one. Dyestuff manufactureres prefer this peroxide paste to PbO_2 anhydride.

Production of Organic Compounds.

Acetic Acid Anhydride.

The uses of electrolytic chlorine should, however, not be restricted to the production of inorganic compounds.

From phosphorus trichloride it is easy to make acetyl chloride, CH_3COCl, the method being described in text books. From acetyl chloride, in turn, it is possible to make acetic acid anhydride which is used in the dyestuff industries, as well as in the manufacture of vanillin, etc. Acetic acid anhydride is formed if 50 kg. of molten sodium acetate are gradually brought to reaction with 50 kg of acetyl chloride in a vessel which is well-cooled with water. By means of a vertical cooling apparatus provision is made to prevent acetyl chloride from escaping in such a way that the gas condenses in the vertical tube and flows back. This operation is to be followed by heating in a steam bath and distilling off the acetic acid anhydride.

Chloroform.

Chloroform is produced by mixing 250 kg. of 30° to 35° chloride of lime with 600 liters of water in a vessel of 2 cubic meters capacity, and adding slowly, with stirring, 20 kg. of acetone. A strong reaction takes place, and, without external heating, pure chloroform distills over. It may be shaken with concentrated sulphuric acid and may again be rectified. With the quantities mentioned above, one gets 32 kg. of chloroform, often somewhat more.

From chloroform it is possible to obtain tetrachlormethane (carbon tetrachloride) in a well-known manner.

Chloral.

Chloral hydrate is obtained by introducing chlorine into

alcohol; it is the well-known anæsthetic. On an industrial scale the manufacture if carried out as follows:

The starting material is 120 kg. of ethyl alcohol. The introduction of chlorine takes six days and takes place under the following conditions.

	Deg. Baume.	Temperature Deg. C.
First day	11	20
Second day	20	40
Third day	28	50
Fourth day	36	60
Fifth day	44	75
Sixth day	50	90

To get these temperatures, it is first necessary to apply artificial cooling and afterwards heating in a steam bath.

During the reaction with chlorine a number of combination products of alcohol with chlorine escape and are condensed.

Chloral, thus produced, is then treated as follows. 450 kg. are mixed with 550 kg. of sulphuric acid 65°, with following distillation. The distillate is again rectified and the material which first passes over (about 60 kg.) is separately collected and again distilled with the next quantity.

Production of Chloral Hydrate in Crusts.—Eighteen kg. of chloral anhydride are mixed in a glass vessel with 1800 grams of water; chalk is then added until the free hydrochloric acid is neutralized; now 50 grams of ammonia, 28 per cent, are added and the whole mass is distilled from a lead vessel in a calcium chloride bath. The distillate is shaken in glass bulbs until the mass is viscous; it is then poured on shallow dishes. In order to harden the crusts, the dishes are placed in a drying room which contains sulphuric acid in lead vessels. After twenty-four hours the crusts are ready; they are taken off and broken into pieces.

Production of Chloral Hydrate Crystals.—Twelve kg. of the distillate, as used for making crusts, are poured into 2 kg. of benzene, free from thiophene, and 50 grams of water are added to the mixture. The mixture is left alone at 20° C. Long needle crystals are formed. They dissolve again after a few days, and up to the tenth day the rhomboeder crystals will be formed in which for chloralhydrate is placed on the market. These crystals are allowed to drop off on a clay funnel and are dried over sulphuric acid.

Dichloracetic Acid.

Dichloracetic acid may be obtained in a simple way from chloralhydrate, as follows: 84 kg. of potassium ferro-cyanide are dissolved in 250 kg. of water, and to this solution 50 kg. of chloralhydrate are added, then boiled in a vessel provided with an inclined cooling tube, so that the liquid condensed in it flows back, while the HCN gas escapes and is condensed in a vessel containing KOH (10 to 20 per cent) to form KCN.

The reaction occurs according to the formula $3CCl_3COH + 3H_2O + 2K_4FeCy_6 = 3CHCl_2COOK + 3KCl + 2K_2FeCy_4 + 6HCN$. After three hours' boiling the solution is filtered. The mixture is evaporated and sulphuric acid is added to the solid residue, causing liberation of dichloracetic acid. $CHCl_2COOH$ is extracted with alcohol, then freed from alcohol and distilled and the brown distillate is rectified.

Methylene Chloride.

Pure chloroform may also be obtained from chloral hydrate in a well-known manner. From chloroform, methylen chloride may then be made. For this purpose 50 kg. of chloroform (in an apparatus provided with an inclined tube, so that any liquid condensing in it flows back) are mixed with an excess of zinc, and hydrochloric acid is added. A vigorous reaction sets in. After three hours the content is distilled off. The distillate consists of methylene chloride, alcohol and unchanged chloroform. In a shaking apparatus water is added to the mixture and afterwards separation is then made. $CHCl_3$ and CH_2Cl_2 are separated as oil, dried with $CaCl_2$ and separated from each other by fractional distillation. Boiling point 41° to 42° C.

Monochloracetic Acid

Monochloracetic acid, $CH_2ClCOOH$, is obtained by passing chlorine into concentrated acetic acid in presence of a catalytic agent, sulphur being suitable. During the introduction of chlorine the liquid is strongly heated on a sand bath. The end of the reaction is determined by measuring the increase of weight. After chlorine has been introduced for twenty hours, the mass generally solidifies, when cooled. Then follows fractional distillation. At 150° C. only a few drops pass over. What passes over at 150° to 190°, is cooled and the solidified portion is sucked off by means of a vacuum pump. The filtrate is again distilled and collected from 170° to 190°. The output from 100 kg. of concentrated acetic acid is 120 kg. of monochloracetic acid.

Trichloracetic Acid.

Concentrated acetic acid is mixed with the theoretical amount of chlorine gas in sun light; this results directly in the formation of trichloracetic acid, CCl_3COOH.

Etylene Chloride.

If etylene is brought to reaction with chlorine, etylene chloride $C_2H_4Cl_2$ is formed. It is purified by washing with dilute potassium hydroxide solution and dried over calcium chloride. This is followed by fractional distillation. The product is collected at 85° C.

Monochlorbenzene.

To 150 kg. benzene C_6H_6 are added 2 kg. of iodine and chlorine gas is introduced with artificial cooling. For removing the iodine, dilute sodium hydroxide solution is used; this is followed by separation of the water layer and fractional distillation. First, the excess of benzene distills over, at 134° C. monochlorbenzene, C_6H_5Cl, while in the distilling apparatus higher chlorides remain back.

Paradichlorbenzene.

p-dichlorbenzene is made as follows: In presence of iodine, benzene is treated with chlorine until the increase in weight corresponds to the theory. The product may in turn be used for the preparation af p-dichlorbenzene.

Paradichloraniline.

One hundred kg. of acetanilide are dissolved in 400 kg. of concentrated acetic acid and dry chlorine is introduced with continuous water-cooling until the increase in weight is 106 kg. When cooled, the mass solidifies. It is then filtered and washed with cold ethyl alcohol and dried. 140 kg. of dichloracetanilide are obtained. It is heated for several hours on a steam bath, in an apparatus provided with an inclined tube, so that any liquid condensing in the tube flows back. This is followed by fractional distillation. The compound is collected at 244° to 246° C.

Benzalchloride.

Benzal chloride, $C_6H_5CHCl_2$, is formed from toluole as follows: 100 kg. of toluole are heated on the steam bath in an apparatus provided with an inclined tube, so that any liquid condensing in the tube flows back. Chlorine is then introduced. First benzyl chloride, $C_6H_5CH_2Cl$, is formed, afterwards benzal chloride. With an excess of chlorine, benzotrichloride would be formed. Chlorine is introduced until the increase of weight is 75 kg. The product is then washed with a dilute alkaline hydroxide solution, dried, distilled and collected at 200° to 207° C.

Metachlorbenzaldehyde.

m-chlorbenzaldehyde is made as follows: 100 kg. of C_6H_5CHO are mixed with 300 kg. of concentrated sulphuric acid, 5 kg. of iodine are added and chlorine is passed through until the calculated increase of weight is 32 kg. The chlorination is completed within two days. The product, thus obtained, is diluted with water and is then left alone.

$C_6H_4 \begin{cases} Cl \\ CHO \end{cases}$ forms as oil; it is separated in a separating appa-

ratus, washed and shaken with bisulphite solution. The solution thus obtained is filtered off from some formed C_6H_5COOH and is decomposed with hydrochloric acid.

$C_6H_4 <^{Cl}_{CHO}$ is formed as oil, which is separated and washed with water. This is followed by rectification. The distillate contains at 200° C. some water, iodine and unchanged benzaldehyde. The portion which distills over from 200° to 260° C., is separately collected.

It contains m. $C_6H_4 <^{Cl}_{OH}$ and dichlorbenzaldehyde. The remaining product which smells strongly, probably consists of trichloraldehydes. The distillate of 20° to 260° C. is repeatedly rectified. m-chlorbenzaldehyde distills over from 210° to 215° C.

From m-chlorbenzaldehyde it is possible to make m-chlorbenzylidenaniline, by dissolution in alcohol and mixing with anilin dissolved in an equal volume of alcohol. Crystals are obtained which are again recrystallized from alcohol.

Conclusion.

In giving the above examples of both inorganic and organic compounds, which may be advantageously produced from electrolytic chlorine, I did not intend to give a complete review of all possible compounds. I have only given the most important ones which I have produced myself either on an industrial scale or on a smaller scale in the laboratory.

I hope I have shown that the use of electrolytic chlorine is not restricted to inorganic compounds, but that there is a large field of profitable applications in organic chemistry. It would appear probable that the electrochemical industries which have been built up at Niagara Falls, and which have so far been restricted to inorganic chemistry, may also become the center of industrial processes of organic chemistry. There is no reason why the United States should not manufacture, itself, the valuable organic products which are now exported, mostly from Germany, to the whole world, and in no small part to the United States, where products and dyestuffs are consumed in steadily increasing quantities.

SOME FIRST PRINCIPLES OF ELECTRICAL RESISTANCE FURNACES.

By F. A. J. FitzGerald.

In a paper[1] read by the writer at a meeting of the American Electrochemical Society, an attempt was made to present certain theoretical considerations in connection with electrical furnaces. As was brought out in the discussion that followed, the paper would have had its value greatly enhanced if actual values had been given instead of purely algebraical expressions. This cannot be denied, but it is a fact that those who use electrical furnaces are not disposed to publish data of this kind, preferring rather to wrap all details of practice in a cloak of secrecy. Nevertheless, a purely theoretical discussion of electric furnaces has its uses, for any one who has worked with them knows that by keeping certain first principles in mind much time may be saved in arriving at a successful result in his experiments. There seem to be valid reasons for believing that the first principles of electric furnaces are not a subject of general knowledge, for if they were, the existence of a number of astonishing patents on electric furnaces that have appeared within the last few years would be impossible. It would be invidious to illustrate this phenomenon by an actual example; however, a purely imaginary case may be cited:

Suppose that in a certain process an electric furnace was used and it was found that by increasing the temperature of the reaction the yield was greatly improved. This might be accomplished by increasing the resistance of the furnace without altering its dimensions in any way, and then using a current of the same amperage as before. In this way the rate at which heat energy would be developed in the furnace would be increased. It is a well-known fact that the heat energy developed by a current I passing through a resistance is equal to I^2R and *ceteris paribus* the temperature to which the resistance is raised by the passage of the current will vary with R. That physical fact is not patentable, nevertheless it is typical of certain patents that are taken out in connection with electrical furnaces; the ingenuity in such patents being found in the way the real principle is befogged by the judicious use of the obscure and cumbersome language characteristic of patent specifications.

In most of the earlier work with the electric furnace the arc was used, but in recent years the tendency in industrial work has been towards the use of the resistance furnace. There are two kinds of resistance furnaces:

(1) That in which the current is passed through a resistance, heating the latter to a high temperature, and the heat is then radiated or conducted to the material on which it is desired to work. Examples of the commercial application of this principle are found in the carborundum furnace, where the current passes through a granular carbon core, which in turn heats the surrounding charge of sand and coke; and in certain furnaces for the treatment of ores, such as those of Keller and Héroult, where the current in part, at least, passes through the slag.

(2) Furnaces in which the current passes through the material under treatment, as in Acheson's graphite furnace, and various furnaces for making calcium carbide.

In studying the principles of these furnaces, it is therefore necessary to consider both the phenomena of the generation of heat in a conductor by the passage of an electric current, and of the distribution of the heat that is generated.

* * *

When an electric current I, of electromotive force E passes through a resistance R, then, by Ohm's law:

$$(1) \qquad I = \frac{E}{R}$$

If W is watts, then the rate at which energy is given out in the resistance is:

$$(2) \qquad W = EI$$

or, expressing the equation in terms of R and I

$$(3) \qquad W = I^2R$$

Assuming that no other forms of energy are produced, heat alone is developed in the resistance, and the rate at which heat is produced is given by the equation

$$(4) \qquad C = JW$$

where C is calories and J is constant. Of the heat generated part is used in raising the temperature of the resistance and part is radiated into space, or, if the resistance is surrounded by some other material is conducted away. As the temperature rises the proportion of heat conducted away increases till finally a constant temperature is reached when the rate at which the heat is conducted away is equal to C as given by equation (4).

The rate at which heat flows from a hot body into a surrounding conducting material is a function of the difference of temperature between the hot body and the conducting material, the surface area of the hot body, and the heat conductivity of the surrounding material. If heat is being generated at a certain rate in the hot body, it follows from this that the temperature to which the hot body will rise is a function of the heat conductivity of the surrounding material, and the area of the hot body. Therefore, for a given material surrounding a resistance in which energy is given out at a definite rate, the temperature to which the resistance rises will vary directly as the surface area of the resistance.

Let it be assumed that a furnace of the Borchers type is

[1] Transactions of American Electrochemical Society, Vol. IV., p. 9.

used. This furnace is shown in longitudinal and transverse section in Fig. 1. A, A′ are large carbon blocks connected to a source of electric current, C is a resistance connecting A and A′, and M is the material which it is desired to heat to a certain temperature. It will first be necessary to determine the conditions under which that temperature is attained, and that will, of course, depend on the rate at which energy is given out in the resistance. Having found the proper rate, that is, the watts required, and knowing the surface area of C, the number of watts per square centimeter required for the object in view are known. If the resistance material C has a length L and a radius P, then for a given temperature and material to be heated we have the equation,

$$(5) \qquad \frac{W}{2\pi PL} = a$$

where a is the constant determined by experiment, and is given in watts per unit area.

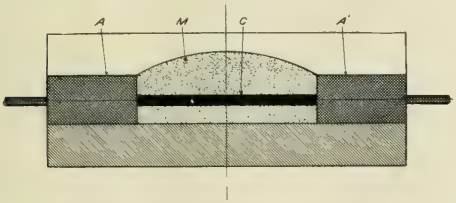


FIG. 1A.—LONGITUDINAL SECTION OF ELECTRIC FURNACE

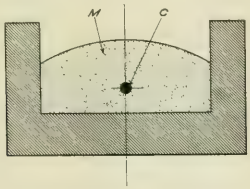


FIG. 1B.—CROSS-SECTION OF ELECTRIC FURNACE

Now let the resistivity[2] of C. be r' at the working temperature, then its resistance will be

$$(6) \qquad R = \frac{r'L}{\pi P^2}$$

If it is desired to use a current I with an e. m. f. E, then, since

$$R = \frac{E}{I}$$

equation (6) becomes

$$(7) \qquad \frac{E}{I} = \frac{r'L}{\pi P^2}$$

Equation (5) may be written

$$(8) \qquad \frac{EI}{2\pi PL} = a$$

From (7) and (8) the dimensions of the heating resistance for any furnace may be calculated.

On account of the variations in electrical resistance of materials with changes in temperature it is usually necessary to have some means of varying the voltage at the furnace terminals. This does not apply to furnaces where the material under treatment is constantly fed in and drawn off when finished, as in the case of certain resistance furnaces used for the reduction of ores. But in furnaces such as those used for the manufacture of carborundum and graphite, the change of resistance with temperature must be allowed for. In practice this is done by using some arrangement by which the voltage at the furnace terminals may be varied. In order that the furnace may be worked at full capacity from start to finish certain conditions must be fulfilled. In both the furnaces mentioned the resistance material through which the current passes is carbon, the electrical resistance of which decreases with increase of temperature. If, therefore, the resistance of the furnace at the beginning of the run is R_1, at the end of the run R_2, the maximum terminal voltage E_2, the minimum voltage E_2 and the total available power W watts, then the conditions for working the furnace at full capacity throughout the run are:

$$(9) \qquad R_1 \leqq \frac{E_1^2}{W}$$

$$(10) \qquad R_2 \geqq \frac{E_2^2}{W}$$

In many cases it is possible to so adjust the resistivity of the heating material that these conditions may readily be fulfilled. The importance of running the furnace at full capacity throughout the whole period of working is obvious. It frequently happens that where power is sold to the manufacturer he pays for his maximum consumption whether he uses it or not, so that any time spent in heating the furnace up to the point where its resistance is reduced so that it uses the maximum power for which it is built is so much loss. It will also appear that there is an important saving in heat losses where the furnace is heated as rapidly as possible.

These equations are useful in designing furnaces where it is necessary to obtain data from experimental furnaces of small size. For this purpose more simple forms of equations connecting the lengths and radii of the heating resistances in furnaces of different capacities may be derived. Equations (7) and (8) may be written,

$$(11) \qquad PL = A\,E\,I$$

$$(12) \qquad \frac{L}{P^2} = B\frac{E}{I}$$

where A and B are constants whose values are

$$(13) \qquad A = \frac{PL}{EI}$$

$$(14) \qquad B = \frac{IL}{EP^2}$$

If, now, it is required to build a furnace using a current I, at E volts, and the unknown length and radius of the heating resistance at L_1 and P_1, respectively, then we have from (13) and (14)

$$(15) \qquad \frac{P_1L_1}{E_1I_1} = \frac{PL}{EI}$$

$$(16) \qquad \frac{I_1L_1}{E_1P_1^2} = \frac{IL}{EP^2}$$

whence

$$(17) \qquad P_1 = P\sqrt[3]{\frac{I^2}{I_1^2}}$$

$$(18) \qquad L_1 = L\frac{E_1}{E}\sqrt[3]{\frac{I_1}{I}}$$

As an example of an application of these equations, an actual experiment may be quoted. The problem was to design a furnace having a capacity of 200 kilowatts, using a current of 4000 amperes at 50 volts. The temperature at the surface of the heating resistance had to have a particular value. Experiments were made on a small scale with the object of find-

[2] Resistivity is the resistance of unit volume of the substance in the form of a cube.

ing out the proper proportions. Details of the methods used in experiments of this sort must be reserved for another place; but the results showed that the desired conditions were obtained with a current of 200 amperes at 100 volts, and a heating resistance 365 cms. long and 10.2 cms. diameter. If these values are substituted in equations (17) and (18) it will be found that the proper length and radius of the heating resistance for the proposed furnace are respectively 495 cms. and 37.6 cms.

In general it will be found that in passing from a small furnace to a large furnace the heating surface of the resistance may be made larger than that calculated from the experimental work with the small furnace. This is due to the greater loss of heat that usually occurs in small furnaces, and will be better appreciated when the conditions governing the flow of heat in the furnace are considered.

Let it be assumed as before that the heating resistance is in the form of a cylinder of length L and radius P, and that it is surrounded with the material which it is desired to heat. The isothermal surfaces about the heating resistance are a series of cylinders coaxial with the heating resistance and the lines of flow of the heat form tubes of flow having the shape of wedges with their edges lying along the axis of the heating resistance. This is shown in Fig. 2, representing the

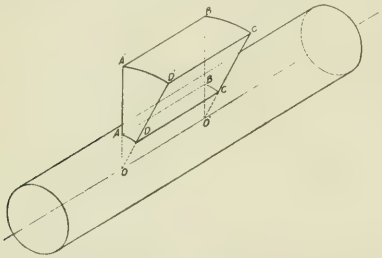


FIG. 2.—PROPAGATION OF HEAT IN RESISTANCE

heating resistance with radius OA equal to P. If any surface A B C D is taken on the heating resistance, and the radii OA, O'B, etc., produced to a cylinder representing one of the isothermal surfaces and having a radius P_1, there is obtained on the latter the surface A' B' C' D'. It will readily be seen that planes parallel to the axis of the cylinder will cut off from the wedge-shaped tubes of flow rectangles having widths proportional to their distances from the axis. Now, when a constant state is reached, so that the temperature of the heating resistance is θ_1 and that of the isothermal under consideration is θ_2, and if the heat conductivity of the material round the heating resistance is K, then the quantity of heat flowing per second is

$$(19) \qquad C = \frac{2\pi LK\,(\theta_1 - \theta_2)}{\log.\ \frac{P_1}{P}}$$

or if $P_1 - P = t$, and t is very small

$$(20) \qquad C = 2\pi LK\,(\theta_1 - \theta_2)\,\frac{P}{t}$$

From this is evident the importance of having the temperature of the heating resistance as high as possible. In general, the object in a furnace process is to convey heat rapidly from the source to the material to be heated. Herein lies one of the great advantages of electric furnaces, for it is possible to obtain very high temperatures in the source of heat. If it be assumed that the minimum temperature at which useful work is done is θ_2 and an isothermal surface where the temperature is θ_3, and having a radius P_2, is taken then the heat flowing from the isothermal θ_2 to θ_3 is

$$(21) \qquad c = \frac{2\pi LK\,(\theta_2 - \theta_3)}{\log.\ \frac{P_2}{P_1}}$$

or if $P_2 - P_1 = t_1$ and t_1 is small

$$(22) \qquad c = 2\pi LK\,(\theta_2 - \theta_3)\,\frac{P_1}{t_1}$$

Now it is evident that the efficiency of the process is given by the equation

$$(23) \qquad \text{Efficiency} = \frac{C - c}{C}$$

From equation (22) it is seen that as P_1, the radius of the isothermal of the limiting temperature is increased the efficiency diminishes. Furthermore, the greater the value of $\theta_1 - \theta_2$ compared with $\theta_2 - \theta_3$, the greater is the value of C compared with c, and hence the greater the efficiency of the process.

The great value in the use of electric furnaces for many processes lies in the high temperatures obtainable, thus permitting the attainment of a high efficiency that could not possibly be obtained where the source of heat has a relatively low temperature. An experiment illustrating this very clearly may be described.

A very intimate mixture of finely pulverized silica and carbon was made and packed in a graphite crucible. The latter was then placed in a Fletcher gas furnace heated with a blast lamp. Even after two hours strong heating no appreciable change was observed in the contents of the crucible. The crucible was then put back in the furnace and heated for about eight hours. Then it was found that a layer of a greenish colored substance was formed next the side of the crucible. The layer was only about 2 mm. thick. This greenish colored substance contained silicon carbide. As is well known this compound can be readily produced in the electric furnace. The enormous quantity of heat required for the production of a minute quantity in the gas furnace is due to the relatively low temperature of the burning gas. Nearly all the heat went to waste because the temperature was far too low.

In practice it frequently happens that the maximum temperature which may be used in the furnace is definitely fixed. Thus, in the manufacture of carborundum the temperature must not be allowed to go beyond that of the decomposition of carborundum. But from what has gone before it is evident that the temperature of the heating resistance should be carried as near to this point as possible. The temperature limit in the manufacture of "siloxicon" is much lower than that of carborundum, for if temperatures as high as that of the carborundum furnace are reached crystalline silicon carbide will be formed. It is evident that in all cases where careful temperature regulation is required, the importance of keeping in mind the principles on which the working of the furnace depends is very great.

The principles of those forms of resistance furnaces in which the current is passed through the material under treatment are somewhat more simple than those already discussed. Here a certain amount of heat must be supplied to a mass of material by the passage of the current.

Taking a simple case let a furnace similar to that shown in Fig. 1, but without the resistance material C connecting the terminals A and A' be assumed. The current flows between A and A' through the charge M, which it is desired to raise to a certain temperature. The rate at which heat is generated will be as given before by equation (4). To attain the desired temperature a certain amount of heat must be supplied, depending upon the mass of the material to be heated. Therefore to bring the mass up to the desired temperature in a certain time a definite number of watts per unit volume must be used. It is frequently the custom to speak of using a certain "current density" in furnaces of this kind, an objectionable

practice unless the electrical resistivity of the material through which the current passes is also given. Since the same material at different temperatures has different values for its electrical resistivity, the proper data to give in all cases are the watts per unit volume.

It has already been shown that the heat lost by radiation from the electric furnace previously considered is given by equation (22) and this also applies here. One of the important details to attend to then is keeping down the radiating surface of the furnace as much as possible. The furnace shown in Fig. 1 has the form of a parallelopiped, and it may readily be shown that the external surface is a minimum for a given volume when the parallelopiped is a cube. The form of a cube would therefore be ideal so far as the losses by heat radiation are concerned. There cannot be the slightest doubt that in actual practice there is not nearly sufficient attention paid to this point.

As the total amount of heat lost according to this equation will depend upon time, it is obvious that in discontinuous processes the temperature of the mass should be raised to the desired point as rapidly as possible.

Finally, in all electric furnaces the question of heat insulation is of immense importance, and is too often overlooked. On account of the very high temperatures used in electric furnace work, and the relatively great cost of the electrical method of generating heat, the necessity of efficient heat insulation is greater than in other processes. Efficient heat insulation is by no means a simple problem, but careful study of the subject is well worth while. In spite of the fact that good heat insulation may often seem to involve considerable cost, yet, when this cost is compared with that of the electrical power which, without it, will go to waste, its value will be quickly recognized.

The question of the efficiency of electric furnace processes is of great interest; but it is doubtful if any calculations as to absolute efficiency are of real value. The data at our disposal for making calculations are so uncertain that the results must be untrustworthy. We know little as to the specific heat of substances at high temperatures, but we are perfectly certain that so far as some of them are concerned the specific heats at high temperatures are quite different from those at low temperatures. In addition to this we only know at present within wide limits the actual temperatures attained. Where chemical reactions are involved we know nothing of the heat exchanges that take place at the high temperatures involved. Finally, in some processes, such, for example, as the production of graphite from amorphous carbon, we cannot form estimates of the heat absorbed in the vaporization of impurities in the carbon, which is nevertheless useful work. Again, in the manufacture of carborundum useful work is done by heating the mass crystals to a high temperature for a considerable length of time, thus obtaining the individual crystals large instead of in a fine needle-like form.

These considerations lead us to conclude that there is at present only one useful way of considering efficiency and that is, relatively. In all electric furnace work a careful account of the energy used should be kept and compared with the output. In this way the number of watts per unit of material produced can be obtained, and where a course of experiments on different furnaces or modifications of one furnace for a particular purpose are undertaken, it may readily be ascertained which form gives the most efficient results.

ARRIVAL OF FOREIGN ENGINEERS.—The first large party of foreign electrical engineers visiting this country to attend the St. Louis Congress, reached New York on August 24, when thirty members of the Associazione Elettrotecnica Italiana arrived on the Princess Irene, direct from Italy. A second Italian party landed on August 25 from the steamer Deutschland. They were met by Messrs. J. W. Lieb, Jr., T. C. Martin, C. W. Rice and C. de Muralt, of the American Institute of Electrical Engineers.

USES OF ACHESON GRAPHITE IN METALLURGICAL RESEARCH.

BY WOOLSEY MCA. JOHNSON.

In a paper read before the American Electrochemical Society in April, 1904 (ELECTROCHEMICAL INDUSTRY, vol. II., page 185, 1904), I described a new type of pyrometallurgical apparatus which was employed in our laboratory for measuring the "reduction temperatures" of the various ores of zinc. This apparatus was made of machined Acheson graphite. It showed such valuable properties for experimental work at high temperatures that we have made of it, contemporaneously with this work, other articles for this general class of work.

Acheson graphite possesses several marked advantages for the above-described purposes. Perhaps the chief of these is the fact that it can be machined on planer, lathe, drill-press, shaper, etc., to about 0.003 in. to any desired shape. This allows one to machine out accurately different parts of an apparatus which can then be assembled to a homogeneous whole. The joints can be either fitted or threaded. In many cases the bar can be machined directly to the proper form. Many articles can be made by hand by means of a sharp chisel or gouge.

The next valuable property of artificial graphite is its high capacity for conducting heat. With any sort of a decently designed experimental furnace, we can be reasonably sure that all parts of a solid graphite crucible are at nearly the same temperature. By drilling a ¾-inch hole in any convenient part of the crucible and inserting in it a pyrometer we have thus the true temperature (or nearly so) of the crucible and its contents. When a crucible of fire clay is used, we can be

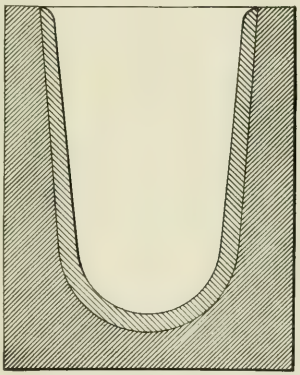


FIG. 1.—BRASQUED GRAPHITE CRUCIBLE MADE FROM 4-INCH ROUND ACHESON GRAPHITE BAR. (CUT ½ SIZE.)

quite sure that unless great care is taken, the charge is not heated uniformly. Especially true is this where the heat is applied locally by the electric current. Where many determinations are made the high thermal conductivity of electric furnace graphite is a great time saver and in a technical laboratory a large money saver.

The third good quality is that artificial graphite will stand without undergoing physical change a higher temperature than any other substance known to chemists. Below 2500° C. it has an extremely small vapor tension and neither melts or sublimes at even a much higher heat. Naturally it is always a reducing agent. By lining the apparatus with a suitable inert oxide, such as alumina, however, it can be employed in a wide range of work.

The fourth good quality of Acheson graphite is that it will stand sudden changes of heat without damage. I have on many occasions seized a red-hot graphite box with a pair of tongs and put it under a stream of water. On looking up I

found that those around had fled and were peeking at me around the corner of a furnace. The stream of water would blacken one side of the box, while the other side was still red. On taking it from beneath the stream the black side would redden in two or three seconds, showing how easily the graphite conducts heat.

I feel sure that one of two alternatives is true. Either

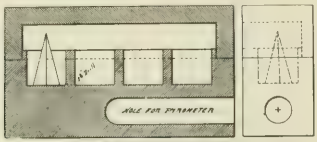


FIG. 2.—HOODED GRAPHITE APPARATUS FOR DETERMINING MELTING POINTS OF SLAGS AND METALS. (CUT ¼ SIZE.)

artificial graphite has almost no coefficient of expansion at high temperature, or, failing this, it has a toughness at high temperatures out of all proportion to its toughness at ordinary temperature.

Its great disadvantage is that when exposed to hot oxygen it slowly wastes away, consequently it should always be used in an atmosphere containing little oxygen.

Perhaps the most serviceable article that can be made out

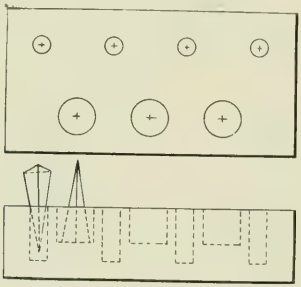


FIG. 3.—RACK FOR SEGER CONES. USED IN TEMPERATURE DETERMINATIONS IN ROASTING FURNACE. (CUT ½ SIZE.)

of graphite is a crucible. A crucible of any desired size from a half inch to 9 inches in diameter can be made by sawing off lengths of sound bars with hand saw and drilling out a cavity with a bit and brace. The walls should be from 3-16 inch to ½ inch thick. The work can be more conveniently done on a drill-press. Large sizes should be drilled on a lathe. The drillings are a fine powder and should be saved, as they can

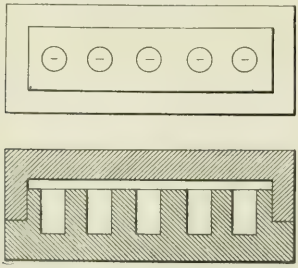


FIG. 4.—COVERED GRAPHITE BOX TO RECEIVE SEGER CONES. THIS BOX CAN BE INSERTED THROUGH MOUTH OF ZINC CONDENSER. (CUT ½ SIZE.)

be put to many uses. Tight-fitting covers also can be made on the lathe.

These crucibles can be brasqued as is an ordinary crucible. A good description of this operation will be found in Howes' "Metallurgical Laboratory Notes," page 115, *et seq.* We use often a dry paste of the brasquing material with water-glass (S. G. = 1.10). A brasqued crucible is shown in Fig. 1.

A tester, as shown in Fig. 4, on page 186 of the May issue of this journal, is useful for determining the boiling points of metals, reaction temperatures of solids. In case the indicator is a gas, a small tube is screwed in the hole. The apparatus is also useful in measuring the decomposition point of sulphates, etc.

Another handy piece of apparatus is that shown in cross-section in the adjoining Fig. 2 for determining the melting points of slags. This can be used at high temperatures above

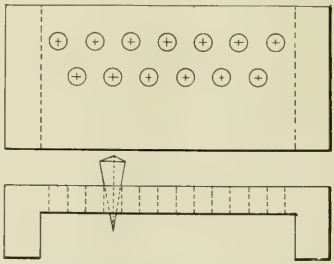


FIG. 5.—RACK FOR SEGER CONES. USED IN TEMPERATURE DETERMINATIONS IN ELECTRIC FURNACE. (CUT ¼ SIZE.)

1600° C., with fusible cones of known melting points as indicators. In this case it is possible to determine the melting points at extremely high temperature. An optical pyrometer could well be used in connection with this apparatus.

Figs. 3 and 4 show forms of apparatus that allow fairly accurate measurements by means of fusible Orton or Seger cones. Fig. 3 is the form I use daily in measuring the temperature of roasting furnaces of the Lanyon Zinc Co., at Iola. The cones are usually inverted, and as the graphite is bedded in the ore, it brings the "tester" quickly to the temperature of the ore. An apparatus of fire clay would delay the mechanically-operated rakes so long as to put daily measurements out of the question.

Fig. 4 is the form which I use in measuring the inside of a retort at the end of the shift. The box is made small with a tightly-fitting cover. It can be inserted on a small paddle through the mouth of a condenser on a zinc furnace.

These measurements can be made at a cost of 5 cents each, and do not require technical skill. A Le Chatelier pyrometer

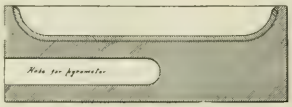


FIG. 6.—CROSS SECTION OF BRASQUED ROASTING DISH. (CUT ¾ SIZE.)

is of use in the laboratory, but for the works it is too delicate. It is, moreover, extremely dangerous to put the couple inside a zinc retort.

Still another application is the brasqued roasting-dish of Fig. 6. This can be used where, in a test, an ore needs to be roasted at definite temperature.

Many possible future uses are in my mind, but most of the above have been given a thorough test. Enough has been said to show what a valuable material Acheson graphite is for factory and laboratory work.

It is a substance whose peculiar properties should be widely known. It is likely that when large sizes can be made Acheson graphite will have a wide use in large-scale, high-temperature work of the future.

WILLIAM H. NICHOLS.

During September the Society of Chemical Industry (London) will hold for the first time its annual general meeting in the United States, where a large number of its members reside. At this meeting Mr. William H. Nichols will succeed Prof. Ramsay as president of the Society, and for the second time in the history of the Society an American will be its president—the first to enjoy this honor having been Dr. Charles F. Chandler, of Columbia University.

While the latter represented chemical science in America, Dr. William H. Nichols was doubtless chosen from his connection with the chemical industries of this country. All will, we believe, agree that no one could be found more worthy to represent chemical enterprise in this country and at the same time represent that fine type of the plucky American captains of industry whose work has placed the United States industrially in the front rank of the nations.

William H. Nichols was born in Brooklyn, N. Y., on January 9, 1852. His father was George H. Nichols, and his mother Sarah E. Harris, both born in Providence, R. I., and of old New England stock. Mr. Nichols graduated from the Polytechnic Institute of Brooklyn in 1868, and from the New York University in 1870, with the degree of B. S. The same institution honored him with the degree of M. S. in 1873 for work done after graduation. In June, 1904, Lafayette College conferred on him the honorary degree of LL. D.

WM. H. NICHOLS.

What he has done for building up chemical industries in general in this country, is well illustrated by the fact that he founded and is president of the General Chemical Co., the largest producers of acids and heavy chemicals in this country. His progressiveness and pluck is indicated by his connection with electrochemistry since he founded and became president of the Nichols Chemical Co., now operating the largest copper refinery in the world. Mr. Nichols is a charter member of the American Chemical Society. He is also largely interested in mining and in the development of metallurgical properties.

Mr. Nichols has always shown a keen interest in education, and especially in technical education. He has delivered various lectures at Lafayette, and at request contributed memoranda to the Moseley Educational Committee, which visited this country from England some time ago.

Mr. Nichols' characteristic energy does not allow him, however, to confine himself to work in industrial chemistry and metallurgy. He has always manifested a strong leaning toward finance and banking. He is a director of some seventeen corporations in all, among them the Corn Exchange Bank, the Title Guarantee & Trust Company and the New York Glucose Company. Whenever Mr. Nichols assumes the duties of a director of a corporation, it means that he will take a very active part in its management. Thus, he is a member of the Executive Committees of the Corn Exchange Bank and of the Title Guarantee & Trust Company.

Mr. Nichols was the third president of the Brooklyn Young Republican Club, Hon. Seth Low being the first, and Horace E. Deming the second. Since the death of James W. Elwell, Mr. Nichols has been chairman of the Board of Trustees of the Clinton Avenue Congregational Church. For several years he has been president of the Congregational Church Extension Society of New York and Brooklyn. He is a member of numerous clubs, including the Chemists' Club, the Hamilton Club, Riding and Driving, Nassau Country Club, University Club of Brooklyn, Down Town Club of New York, Rembrandt Club, and various others.

Mr. Nichols has always manifested a keen interest in outdoor sports. He has a beautiful place upon the St. Lawrence River and is an enthusiast in yachting, fishing, shooting and golfing. This keeps him in good health and permits him to bear cheerfully the many burdens of his duties.

There is, however, one other characteristic which has assisted him greatly in his many enterprises. This is his sharp judgment of men. He has always been far-sighted and fortunate in the selection of his lieutenants, and to those chosen he gives absolute confidence. He is highly esteemed by his subordinates, while everybody who has to deal with him in business matters is impressed by the frankness and integrity of his character.

SULPHURIC ACID BY THE CONTACT PROCESS.

It is quite possible that the apparently clearer conception of the constitution of matter which is being given to the world at the present time, will shed more light on that mysterious chemical or possibly electrochemical property, catalysis. This power of causing radical changes in the composition of the surrounding medium with no detectable alteration in the catalyzer itself is possessed by a number of substances, particularly in a fine state of division. Finely divided platinum, however, presents the most conspicuous example of catalytic conversion.

Several explanations of this phenomenon have been suggested, but none of them has passed the hypothetical stage. The particular action with which we have to deal is one of simple oxidation, that of sulphurous anhydride to the sulphuric compound. It seems reasonable to suppose that this conversion has an intimate connection with the power of platinum sponge to occlude gases, notably oxygen (several hundred volumes being occluded at the ordinary temperature), but it is difficult to comprehend how a substance may oxidize for an indefinite time under constant conditions a surrounding gas, with the occlusion hypothesis only to work upon. Nevertheless, this platinum surely does.

Another theory is founded upon the power of platinum to remove from the space adjacent to it a great amount of sensible heat. There are several good reasons for believing that the compound formed by burning sulphur would be sulphur trioxide if the part played by the external conditions was nil. For instance, a very considerable amount of sulphuric anhydride is invariably found in ordinary "burner gas," and by carefully avoiding an undue rise of temperature in the kilns, the proportion of sulphuric anhydride can be greatly increased. Also, the heat of formation of sulphuric anhydride being in excess of that of sulphur dioxide is an indication in favor of the production of sulphuric anhydride when the reacting elements are allowed free play. But sulphuric anhydride is dissociated at a comparatively low temperature, (below 700° C.) and the heat evolved in its formation is great (22,000 Cal). In consequence, therefore, sulphur dioxide predominates in the gaseous mixture formed by the combustion of sulphur or pyrites. This predomination does not

obtain, however, after the burner gases, properly purified, have been passed through platinum-bearing material, and thus has arisen the assumption that the function of the platinum is to destroy the sensible heat, and to maintain the temperature below the decomposition point of sulphuric anhydride. Here, also, a limit to the catalytic power of platinum is indicated if the heat evolved is supposed to be simply conducted away, and it scarcely seems probable that if this heat energy were converted into thermo-electric energy, as has also been suggested, that such action would have escaped detection by one of the many investigators of the subject. Fortunately, however, our inability to follow the molecules' every move when in the neighborhood of finely divided platinum at the right temperature, does not prevent us from controlling its course through a comparatively simple apparatus, and with drawing therefrom a new and more valuable substance.

Sir Humphrey Davy first observed the catalytic action of platinum in 1818. But for a period of over fifty years thereafter, no practical results were achieved, though many proposals were at intervals published. Notably, Phillips, of Bristol, England, patented in 1830 a process for manufacturing sulphuric anhydride by catalysis.

The researches of Winkler, published in 1875, combined with an increased demand for the fuming acids, are no doubt responsible for the position of the industry to-day.

Winkler was chiefly engaged with the production of the so-called Nordhausen Oil of Vitriol from copperas, and finally from weaker sulphuric acid itself. By the decomposition of these substances the sulphur dioxide and oxygen were obtained in stoichometrical quantities, a condition Winkler believed necessary for profitable operation.

The obvious object of these many years' work was the production of sulphuric acid from burner gases, and it was left for Dr. Rudolf Knietsch, of the Badische Anilin and Soda Fabrik to accomplish the result on a profitable commercial scale.

It is presupposed that every one is familiar with the production of sulphur dioxide either from pyrites or brimstone, therefore a description of the kiln department of an anhydride plant will be omitted.

Experience has shown that the most economical procedure in operating either a contact or chamber sulphuric acid plant, considering both roasting and acid proper departments, is to produce gas of the following composition: Sulphur dioxide 7 per cent, oxygen 10 per cent, and nitrogen 83 per cent. Therefore the roasting of the brimstone or pyrites needs no particular discussion in the consideration of the contact method.

As soon, however, as the gas has left the kiln room, radical departures from the older practice are encountered. In fact the procedure is exactly reversed. In the chamber process, including stills and arsenic purification plants, the acid is made containing the impurities, arsenic, antimony, silenium, tellurium, iron, nitrogen compounds, etc., these substances being eliminated, subsequent to the withdrawal of the acid from the chambers. But the contact process necessitates an actual chemical elimination of everything except sulphur dioxide, oxygen and nitrogen before the gas is admitted to the contact compartments. The experience of every manufacturer who has installed a contact plant will bear testimony to the truth of this statement. The difficulty of effecting the purification was for a considerable time apparently insurmountable, it yielding only to indefatigable efforts combined with elaborate and expensive experiments.

Arsenic, which shares in the metallurgical world the odium that "basic salts" enjoy in a laboratory, was found to be the prime trouble-maker, chiefly because under the existing conditions it acts with great versatility in its chemical attachments and is most evasive in whatever role it elects to act.

In the first place, arsenical fume has been recognized for years as an exceedingly difficult substance to deposit from gases, and this is naturally present in the combustion products of arsenical pyrites. Unfortunately, most pyrites are arsenical.

Secondly, arsenious oxide, sulphuric acid and iron flues form a combination suitable for the production of arseniurretted hydrogen. The sulphuric acid must therefore be prevented from condensing in iron flues. It has also been found advantageous to cool the gas gradually, condensation being less easily effected with rapid extration of heat. Another phase in which arsenic appeared as a source of annoyance was in its tendency to accompany, persistently, extremely minute particles of sublimed sulphur.

A supplementary oxidation of the gases was therefore necessary to break the union between the arsenic and sulphur. This has been most effectually accomplished by the introduction of a jet of steam, causing at the same time a perfect homogeneity of the gas.

The mechanical impurities carried along by the current of gas, such as iron oxide and zinc oxide frequently met with, can be isolated byordinary dust chambers and scrubbing towers.

As has been previously noted, the heat of formation of sulphuric anhydride is great, and thus arises at once a most interesting and important feature of the contact process.

Also, before the reaction expressed by the equation $SO_2 + O = SO_3 + 22{,}000$ Cal., takes place quantitatively, the reacting gases must be raised to a temperature of at least 375° C. The limits within which the reaction takes place are wider than was for a time generally believed, but it is true that the heat developed by the combination will greatly reduce the yield of sulphuric anhydride if not removed.

The two facts, that a large number of heat units are generated, and that they have a disastrous effect on the completeness of the conversion, has given rise to, as termed by Knietsch, "regenerating cooling." That is, the heat extracted from the platinum mass in operation is used to heat the gases approaching the contact chamber to the required initial temperature, or, expressed differently, the cool ingoing gases are employed to check the rise of temperature above the decomposition point of sulphuric anhydride. Thereby is effected an economy in platinum space and fuel.

The first sucessful application of this principle was that of R. Knietsch, assignor to the Badische Anilin and Soda Fabrik of Ludwigshafen, Germany (U. S. Patent 688,020). Other inventors have subsequently employed the thermo-chemical effects of the reaction with a similar result, but their method of procedure has of necessity differed materially from that of Knietsch. The plants operating under the patents of Knietsch, Max Schroeder (controlled in the U. S. by the New Jersey Zinc Co., U. S. Patent 742,502) and Herreshoff (controlled by the General Chemical Co., U. S. Patents 719,332 and 719,333) produce by far the greater amount of acid made by the contact method. It will therefore be interesting to note briefly how in these three cases infringement has been obviated in the matter of "regenerating cooling."

Knietsch's apparatus consists in a well-insulated vessel of iron or masonry provided with "ingress and egress" passages, arranged, however, so that within the space there are counter currents of gas. The comparatively cool sulphurous acid from the purifying apparatus traveling upward, completely surrounding a number of iron tubes containing the active substances through which the ascending current is forced to pass in the opposite direction before leaving the apparatus. Provision is also made for introducing the sulphurous acid at the center and top of the chamber, thus permitting a more perfect regulation of temperature without varying the quantity of gas operated upon.

Schroeder brings the purified sulphur gas to the required temperature by passing it through conduits placed in the kilns or by means of a heat transferrer adjacent to the kilns, thus employing the heat of burning pyrites or sulphur instead of that developed by the oxidation of sulphur dioxide.

Herreshoff makes use of the heat liberated in the contact chambers, but his method differs from that of Knietsch in that

he effects a transfer of heat in a separate specially constructed apparatus external to the contact mass. Therefore, the gas before entering the converting pots, of which there are two, travels through two separate vessels simultaneously and in close proximity to a counter current of the highly heated sulphuric anhydride leaving the contact pots.

It may thus be seen that the temperature of the platinized material is not subject to control from overheating, except by varying the amount of sulphur dioxide differing in this respect from the practice of Knietsch.

It is probably for this reason that W. C. Ferguson, also assignor to the General Chemical Co., subsequently patented an apparatus consisting of a "plurality of contact chambers," of such dimensions that the sulphur dioxide is not wholly oxidized in the first one, and he further provides means for introducing a regulable supply of oxygen or air into the stream of gas passing from one contact pot to the next. (U. S. Patent 723,595).

This method of operation permits of a more simply constructed contact vessel than that employed by Knietsch. This would, however, appear to be of little moment, as the method necessitates the heat transferring apparatus which are built on the same principle as Knietsch's converters.

Instead of disposing the platinized asbestos in tubes Herreshoff places it evenly on perforated plates arranged one above the other about an inch apart, the current of gas naturally being down.

In all of the methods referred to between 95 per cent and 100 per cent of the sulphur dioxide has undergone conversion to sulphur trioxide and is thus ready to be absorbed to produce acid of the desired strength, rarely under 98 per cent, with the actual solid anhydride for the maximum limit.

It is a surprising fact that water, even under conditions of most intimate contact, fails to unite, except to a slight degree, with the sulphuric anhydride contained in the gases issuing from the converter, or more properly from the cooler, as it is, of course, necessary to reduce the temperature of the stream before passing the gases into the absorbing device.

It might be remarked as a matter of general interest that a solution of barium hydrate, and even of caustic soda, allows the sulphuric anhydride to bubble through them with only slight absorption.

In the presence of a large amount of sulphuric acid, however, the anhydride is completely hydrated. Thus it comes about that strong sulphuric acid, 96 per cent and over, is generally used as the absorbing agent.

The acid in the absorbers, usually two or three in number, is kept at practically constant strength by the addition of water or, better still, chamber acid, if available, the supply being regulated by the amount of strong acid withdrawn from the apparatus and the amount of sulphuric anhydride introduced.

A word in regard to the various contact materials. It has been found that the greater the surface of active substance exposed, the more perfect is the reaction. In this particular, platinized asbestos fulfills the requirements better than anything else. This is prepared by treating a highly silicious fibre with platinum chloride solution, together with a reducing agent, oxalic acid, for instance, and heating the mass so prepared to drive off hydrochloric acid, and other volatile matter, leaving only the platinum deposited on the asbestos in a very fine state of division. In case of contamination, it is not a simple matter to recover the platinum entirely by working over the platinized asbestos. Schroeder therefore has patented the use of a soluble salt as a carrier for platinum, such as "soluble salts of the alkalies of the alkaline earths" (U. S. patent 636,925). To recover the platinum it is obviously only necessary to dissolve the soluble matter with water.

Other catalytic agents that have been proposed are freshly prepared ferric oxide made by roasting pyrites, anhydrous copper sulphate, copper oxide and chromic oxide.

It is a much disputed point whether the contact process will in time become a competitor with the lead chambers for the production of acid below 60° Be'.

On the authority of one of the most successful users of the contact process abroad, chambers are inevitably doomed in localities where the conditions are reasonably favorable for contact operation. Such conditions would probably be moderate priced fuel and a fair demand for the higher grades of acid.

The recent improvement effected in the chamber process is a remarkable instance of response to threatened competition by an old-established and most conservative industry. A few years back 20 cu. ft. of chamber space and 0.025 pounds of niter per pound sulphur burned was considered fair practice. At the present time, in up-to-date plants these figures must be changed to 10 or 12 cu. ft. and 0.015 pound niter. Improved construction of the towers, the use of fans to insure uniformity of operation regardless of atmospheric conditions, and to thoroughly mix the gases, and running nitric acid down the Glover tower, instead of "potting" niter, have been the chief contributors to this result.

In the concentrating department Kessler stills have brought down the cost of producing 66° Be' and 66½° Be' acid.

In regard to first cost, a chamber plant is probably somewhat less expensive to erect, but occupies many times the space required by a contact plant, and entails a very much greater repair bill.

If, however, stills be included there is no doubt a handsome balance in favor of the new process.

Some idea of the magnitude of the sulphuric acid industry can be obtained from the following figures taken from the census report of 1900:

No. of establishments (all Chamber) 127
50° acid produced, 1,906,878,903 pounds.
60° acid produced, 34,023,131 pounds.
66° acid produced, 754,558,455 pounds.
Brimstone burned, 53,997,752 pounds.
Pyrites burned, 673,076,695 pounds.
Value acid, $14,247,185.

THE MANUFACTURE OF FERRO-ALLOYS IN THE ELECTRIC FURNACE.

By George P. Scholl, Ph. D.

Only such ferro-alloys as are manufactured on an industrial scale in practice will be dealt with in this article. Alloys which have been made on a laboratory scale, and for scientific purposes only, will, therefore, not be considered. As the manufacture of the first named class of alloys has within recent years, and especially in Europe, assumed quite large proportions, a brief review of the subject will not be without interest.

That the ferro-alloys are of the greatest importance as well to the metallurgist as to the practical mechanic is such a self-evident truth that it hardly needs restatement. To the latter it is brought home very forcibly by the practical revolution of the old methods of running machine tools through the introduction of the modern high-speed tool steels in the manufacture of which ferro-alloys obtained in the electric furnace play a prominent part. And the end is not yet. With reference to this point it may be permitted to quote the closing remarks of Mr. W. Metcalf, in a paper on alloy steels, read at the June meeting of the American Society for Testing Materials, "The making and using of steel containing practically only carbon and iron, with some modifications made by the use of small quantities of manganese, silicon, tungsten and nickel have occupied the best minds in the manufacturing and engineering world for many years. At the close of the century it was customary to "point with pride" and to assume that so much had been done and so much was known, that there was no room for more revolutionary changes, and that the coming generation had only to tag along, utilizing these

great advances with ease and comfort to themselves, and with blessings upon their predecessors. Now, in the first five years of the twentieth century, we older men find ourselves standing on our heads once more. A revolution has come already, and we can look forward to a splendid opening for the best energy and thought of the succeeding generation."

The problem of the application of the electric furnace to the manufacture of the various ferro-alloys has received considerable attention in Europe, especially in France. The principal stimulus to research in that direction was given by the crisis which occurred in the calcium carbide industry several years ago, on account of the enormous overproduction of this article. As many more factories had been built than were required to furnish the world's supply, the managers of the carbide works found themselves compelled to find other things which could be manufactured in their carbide furnaces. The latter could be directly applied to the manufacture of ferro-chromium and ferro-silicon, and products could be obtained, which, crude as they were considered from the standpoint of latter day purity, could at least compare favorably with the products of the blast furnace or the crucible. Gradually, however, an evolution took place, as the demand for purer materials on the part of the steel makers became greater, and at the present time alloys of a purity, especially in regard to carbon, unknown a few years ago, can readily be obtained in the market. Ferro-chromium furnishes a good illustration in this respect. The first ferro-chromium alloys manufactured in the electric furnace, adapted as it was from the manufacture of calcium carbide, contained from 7 to 9 per cent of carbon. As it was not very difficult to make such alloys in the electric furnace, an over-production was soon apparent, and prices went to smash. A tendency to cut down the percentage of carbon, however, gradually manifested itself, and processes were devised to accomplish this, so that at present, according to Dujardin, the engineer in charge of the sales office of the Comptoir International du Ferro Silicium, in Düsseldorf, Germany, there is no demand whatever in Germany for the ferro-chromium containing above 5 or 6 per cent of carbon, the alloys most in demand being those that contain between 4 and 5 per cent of carbon. The products furnished by the Société La Néo-Métallurgie in Rochefort sur Mayenne, one of which contains 0.5 per cent, and the other 2 per cent of carbon, are much appreciated. That an article with such a low percentage of carbon is much higher priced than the ordinary, goes without saying.

The industrial application of the electric furnace to the manufacture of the ferro-alloys has been somewhat lagging behind in this country, though there are some notable exceptions in the case of the Willson Aluminium Company, and the well-known and indefatigable investigator, A. J. Rossi, who has paid particular attention to the problems for a number of years, and especially to the manufacture of ferro-titanium. The causes for this apparent lack of interest are varied. In the first instance, the stimulus due to the crisis in the carbide industry was lacking, as there was no over-production of carbide in this country, owing to the consolidation of the various carbide works. In the second place, the price for hydro-electric power is much less in Europe, and especially in France, than it is in this country.

Albert Keller, of Keller, Leleux & Co., the well-known French electro-metallurgist, in a paper read before the June, 1903, meeting of the British Iron and Steel Institute, estimated the cost of an electric kilowatt year as 50 francs ($9.70). The price charged at Niagara Falls is more than double that amount. If the assertion of Simpson (Electrochemical Industry, Vol. I, page 278), that under favorable conditions electric power can be produced for less than $4 per electric horsepower year, can be realized, conditions would be different.

That manufacturers in this country find it hard to compete under these circumstances against the foreign manufacturers, who have the advantage over them in cheaper power and labor, is pretty evident. In addition to this, the ferro-alloys of whatever description coming into this country only pay a duty of $4 per ton, as they are being classed by the Custom House officials as similar to ferro-manganese and not specially provided for in the tariff act. A case in which this question is involved is at present being taken before the Supreme Court of the United States. It involves the four products ferro-chromium, ferro-tungsten, ferro-molybdenum and ferro-vanadium, the duty on which had been assessed at 20 per cent ad valorem, as unwrought metals. The importers appealed from this decision to the Board of General Appraisers, which reversed the local appraiser and decided upon the duty of $4 per ton. The case was appealed to the United States Circuit Court, which has quite recently given its decision upholding that of the Board of General Appraisers. The Treasury Department has, in view of the importance of the case, decided to carry the matter before the Supreme Court. It is pointed out by the Willson Aluminium Company, who have co-operated with the Treasury officials in this litigation, that ferro-chromium is taxed by similitude with ferro-silicon, ferro-manganese, etc., at $4 per ton, though the price of the two former varies from $28 in the first to $50 per ton in the second case, while ferro-chrome is worth at least $250 per ton. The final settlement of this case will be of great interest.

The furnaces used for manufacturing the ferro-alloys are of various types. In the beginning they were simply adaptations of the ordinary carbide furnaces, with slight modifications. Gradually, however, their construction became more adapted to the needs of the product. One of the prime considerations was the production of pure materials, especially as regards the amount of carbon which they contain. This led to the devising of furnaces with the object of eliminating as much as possible the danger of contamination by the electrodes, by keeping the material under treatment out of contact with them. Further efforts were directed towards increasing the efficiency of the furnaces and minimizing the losses from the radation of heat. Considerable improvements have also been made in the contrivances designed to effect the regulation and control of the electrodes and to facilitate their removal and replacement. Much improvement has also been made in reducing the losses by volatilization by paying proper regard to the requisite current density and temperature.

The principal aim in these furnaces has been to reach temperatures which lie between that of the ordinary metallurgical melting furnace and that produced by the electric arc.

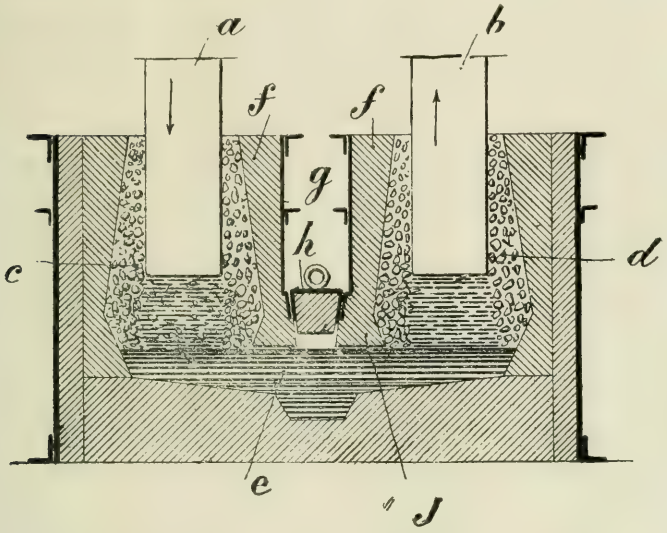
Considerations, such as outlined above, led Héroult, the well-known French electrometallurgist, to the construction of a furnace, in which two separate arcs in series are used, which play through an insulating layer of slag between the fused conducting material on one hand and the two electrodes on the other hand. A shunt circuit between each of the electrodes and the fused material includes two voltmeters, the indications of which serve to constantly verify and regulate the positions of the electrodes and to indicate whether the furnace is working properly or not. Furnace constructions by Héroult adapted for the manufacture of ferro-alloys have been described in Electrochemical Industry by Héroult himself, as well as by the writer in his monthly analysis of current electrochemical patents. (See Electrochemical Industry, Vol. I, pages 449, 63, 287, 467).

Constructions by Albert Keller, of Keller, Leleux & Co., Kerousse, France, which bear a certain likeness to the constructions of Héroult, are described in Electrochemical Industry, Vol. I, page 163. A construction by the same inventor, recently patented in France, to be used for the manufacture of metals and their alloys, is shown in cross-section in the accompanying illustration. It has two electrodes, *a* and *b*, which are placed in separate compartments, *c* and *d*, formed

by the interposition of a construction, *f*, of refractory material.

A plug, *h*, accessible through space, *g* allows communication with the interior of the furnace, either for the introduction of additions or the taking of samples. The fused alloy, *e*, accumulates on the bottom. The advantage claimed for this construction is the prevention of secondary actions between the electrodes, such as occur when they are both plunged adjacent to each other into the material under treatment. The electrodes are of different polarity, and two or more of them per pole can of course be employed.

Another principle is made use of by Girod, the manager of the Albertville works. His furnace was illustrated in a paper by Mr. P. McN. Bennie, in the August issue of ELECTROCHEMICAL INDUSTRY, page 309



It is claimed that the temperature can be regulated at will; it may be maintained at less than 500° C., and go as far as 3500° to 4000° C. Ferro-tungsten of 85 per cent is stated to have been produced in this furnace. The Usine Electro-Metallurgique Albertville produces ferro-molybdenum, ferro-chromium, ferro-tungsten, ferro-vanadium, etc.

A different method for the manufacture of the ferro alloys in the electric furnace has lately been described by A. J. Rossi in ELECTROCHEMICAL INDUSTRY, Vol. I., page 523. It consists briefly in charging metallic aluminium in waffles, ingots, scrap or the like into an electric furnace and melting it by the current. The metallic oxide to be reduced is then introduced, when the aluminium oxidizes with incandescence, the furnace becoming glowing white. The current is then reduced considerably or stopped entirely until the intensity of the reaction is over, and it is then turned on again to keep the product in a molten state for some time longer, when they can be freed from any aluminium left in them by the addition of small quantities of the original oxide used. He claims some advantage over the Goldschmidt process of reduction in a crucible by powdered aluminium as used by the Allgemeine Thermit Gesellschaft, Essen, Germany, which also manufactures various ferro-alloys. The latter process has been described at length in ELECTROCHEMICAL INDUSTRY by Dr. Goldschmidt himself as well as by the writer. (ELECTROCHEMICAL INDUSTRY, Vol. I., pages 527 and 175.)

FERRO-SILICON.

This alloy has been one of the first to be manufactured on a commercial scale in the electric furnace, and its production at the present day has assumed quite large proportions. In Europe, according to Pitaval, in a paper read before the French Société de l'Est (Journ. de l'Electrolyse, Vol. 13, page 3), ferro-alloys, rich in silicon, are made in the following establishments: Compagnie Generale d'Electrochimie, Bozel, Savoy; La Volta Lyonnaise, Moutiers, Savoy; Griesheim Electron Gesellschaft, Griesheim, Baden; Allegemeine Carbidwerke Actiengesellschaft, Mattrei, Austria; Kellner, Partington Pulp Company, Shapsborg, Norway, which form one sales group. Another group comprises the Bosnische Electricitaets Gesellschaft, Jajce, Bosnia; the Schuckert Society at Meran, Tyrol; the Société des Usines Electriques de la Lonza, at Plan du Var, France, and at Gampel, Switzerland; the Lechbruch works at Lechbruch, Bavaria and the works of the Schuckert Society at Hafslund, Norway. These eleven works have constituted a selling syndicate in Paris. The independent concerns are: The Société Electrométallurgique Francaise, at La Praz, Savoy; the Usine du Giffre, a part of whose power is rented to the Société La Néo-Métallurgie; the Compagnie Electrothermique Keller, Leleux & Co., at Livet; the Société des Carbures Métalliques at Notre Dame de Briancon and the Société des Usines Electriques de Hagneck, at Bienne, Switzerland. The above works, however, do not devote themselves exclusively to the production of ferro-silicon.

The methods applicable to the production of ferro-silicon are different. It can be prepared as in the blast furnace by the reduction of iron ores and siliceous materials, or what amounts to the same thing, by the reduction of low grade iron ores, containing a large amount of silica, and which would ordinarily be of very little value for the blast furnace process. Gin (see ELECTROCHEMICAL INDUSTRY, Vol. I., page 131) has proposed metalliferous slags from the acid Bessemer or Siemens-Martin furnace, which he proposes to treat with a current at 25 to 30 volts, the "power density" (the number of volts per square centimeter of the perpendicular cross-section of the electrode) not to exceed 70 volts in order to avoid losses through excessive volatilization.

A second method consists in the reduction of silica by carbon, and its immediate absorption by metallic iron, which is added as such. The iron in this case does not play any role in the reduction, but simply serves as collector and retainer for the silicon. As stated by Jouve (Journ. de l'Electrolyse, August 1, 1902), the silicon is more volatile than the iron under these conditions, and moreover, it has a specific gravity quite close to that of the mixture of carbon and silica, which is in a half molten and very viscous condition. An emulsion of silicon is, therefore, formed in the mass, as the silicon is produced in very fine particles. It therefore has a tendency to remain in the mass and not to flow down to the bottom of the furnace. It is seized upon by the molten iron and the alloy collects on the bottom.

(*To be continued.*)

The Congress of Arts and Science will be held in St. Louis from September 19 to 25. The idea of this congress grew out of the thought that the sub-division and multiplication of specialties has reached a stage at which it would be desirable to bring the scattered sciences into mutual relations. Section X. is devoted to Chemistry.

THE ELECTRICAL PROPERTIES OF THE FILMS THAT FORM ON ALUMINIUM ANODES.

By William Roy Mott.

The insulating films that form on aluminium anodes will be considered in this paper as regards their specific resistance, insulating strength, and specific inductive capacity. These properties can be calculated with the data given in a previous paper[1] on the dimensions of the film. The thinness of the insulating layer gives us a condenser of large capacity; and since as anode, the insulating effect is very great, and as cathode almost nil, thus we obtain with an aluminium electrode an excellent check value, permitting current to flow in only one direction. These two well-known electrical devices, the aluminium electrolytic condenser and rectifier, are of great potential, engineering importance, and so it is hoped that the considerations presented here may aid in the practical work, as well as in the theoretical development. From a theoretical standpoint, much interest attaches to the exact *modus operandi* of the aluminium anode process. An open question[2] of long standing, both with regard to the electric arc and the aluminium anode is "Does the polarizing effect depend upon a high resistance or a counter electro-motive force?"

Since Streintz's time (1887) the prevailing view has been that the effect is due to a dielectric polarization of a thin film of great resistance. But Cook has recently argued in favor of a true counter electromotive force, as against the resistance idea. His argument and work consist in showing that the discharge potential of aluminium electrodes is nearly equal to the impressed voltage, and so he concludes that the difference between these voltages is used up in C R drop. Cook measured by Kohlrausch's method the resistance of two aluminium electrodes immersed in an alum solution and found it to be low. But how can one get reliable results on conductivity with Kohlrausch's apparatus in the presence of large capacity current? So likewise the other work does not prove the presence of a counter electromotive force such as would be observed in a circuit containing a motor or storage battery. A condenser in parallel with a high resistance would produce the effect observed, *i. e.*, high discharge potentials.

Such an arrangement is shown in Fig. 1, where the condenser (C) and the resistance (R) are in parallel. If a steady pressure is put across *a* and *b*, then a steady current will flow that can be calculated from Ohm's law. The dielectric polarization on C can have no effect on the steady current in R. Now, breaking the circuit and reading the discharge potential, it should be nearly equal to the impressed pressure. Similar effects may be obtained with other arrangements where no real counter electromotive force affects the flow of a steady current. For example, apparatus containing self-induction should not be used in circuits where discharge potentials are being read. These facts make it plain that the postulation of a true counter electromotive force is not always necessary in an electrical circuit giving high discharge potentials. In the present case the resistance (R) and capacity (C) are merged together into one apparatus called the aluminium electrolytic condenser.

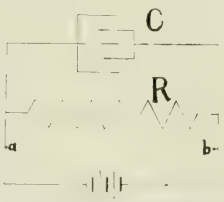


FIG. 1.—ARRANGEMENT OF EXPERIMENT.

The question has been asked as to a condenser with an imperfect insulator for dielectric, "Is the steady current that flows affected by the dielectric polarization?" Most physicists answer this question in the negative. For example, Klemencic[3] in working with the mica condenser calculates the specific resistance of mica (silicate of aluminium) as 6×10^{15} ohms per cubic centimeter from the leakage current of the condenser. One more objection to Cook's view is that it involves a startling exception to Ohm's law. Does a film subjected to dielectric stress change its resistance?

In view of these facts showing the difference between dielectric polarization and ordinary electrolytic polarization, the author of this paper believes that the best explanation of the behavior of the aluminium anode is found in a film of *great resistance* and not in a counter electromotive force similar to that obtained in an electrical circuit charging storage batteries, etc. After a brief reference to the early work upon the aluminium anode, this idea of high resistance will be considered in fullest detail.

Asymmetric, insulating effects have been studied for a long time. Before the separation of metallic aluminium by Wöhler in 1826, asymmetrical resistance had been observed and classified by Erman in 1806. He found that dried soap acts as an asymmetrical resistance. Later, in Faraday's time, the passive state of metals was extensively investigated, but aluminium was not included in this work. When massive aluminium became generally available, tests were made on its use in a primary battery and its position in the electrochemical series. Prominent workers in this direction were Poggendorff, Wheatstone, Heeren and Karmarsch, and Hulot. Buff (1857) followed up this line of work and discovered the insulating effect of an aluminium anode. Independently, Planté[4] (1859) discovered the same effect. Planté says: "If the oxide is insoluble and a bad conductor, then the current is almost entirely stopped. This is what one observes very plainly with aluminium in acidulated water." The work begun by Wheatstone, Buff, Planté, Tait and Ducretet was continued by Beetz, Cail, Slouguinoff, Neyreneuf, Streintz, and some hundred other workers. References will be made to these as occasion arises. The consideration of the specific resistance of the film that forms on aluminium anodes is the subject of the next section.

Specific Resistance of the Film Formed with Phosphates.

The most important work done on leakage current is that of Burgess and Hambuechen.[5] They determined the leakage current with both direct and alternating pressure, and they found the latter to give the larger leakage current making all possible allowance for the capacity effect. They showed that as cathode the hydrogen disrupts the film and destroys it in spots; so on reversal of the current, repair must be made on these spots before the insulation becomes effective. They found that aqueous solutions (of phosphates, borax, etc.) require much longer time for effecting this repair than certain fused[6] electrolytes. With the latter, the time was reduced to 1/1100 second at the beginning of the sine wave.

Experiments were made by the author to determine the resistance of the film formed in disodium hydrogen phosphate solutions. Some conditions are of minor importance, such as the concentration of the electrolyte and the size of the electrode; others are of great importance, such as the temperature, the purity of the electrolyte and the effect of incomplete formation of the film.[7] The addition of sulphuric acid reduces the insulating effect, and the addition of halogen salts[8] destroys it. The effect of increasing the temperature is bad, as Pollak and others have observed. An aluminium anode (effective area, 15 sq. cm.) and a lead cathode were used on a direct current circuit in an electrolytic cell containing 1/10 normal solution of disodium hydrogen phosphate. (A saturated solution would have behaved in the same way).

---

[1] Electrochemical Industry, July, 1904.
[2] See discussion by Prof. Ayrton in connection with a paper of Taylor and Inglis. Chemical News (London), 86, page 265, November 28, 1902.
[3] Wien. Akad. Ber. 96, page 827, 1888.
[4] See Comptes Rendus, 49, p. 402, September 19, 1859.
[5] See Trans. Am. Electrochem. Soc. 1, p. 147, 1902. Western Electrician, 30, p. 273, 1902. The Wisconsin Engineer, 7, December, 1902. Electrochemical Industry, January, 1903. U. S. P., No. 732, 616, June, 1903. Electrical Review (New York), 44, p. 319, February 27, 1904. Scientific American Supplement, No. 1478, p. 23,679, April 30, 1904.
[6] Discovered by Hambuechen in 1900-1901.
[7] See previous paper, loc. cit.
[8] See Taylor and Inglis, Phil. Mag. (6), 5, 301 (1903).

The steady current was read at increasing voltages. A few of these values are given in Table I. They are plotted on Fig. 2.

TABLE I.—EFFECT OF TEMPERATURE ON FILM RESISTANCE.

Volts.	Amp.	Temp.	Volts.	Amp.	Temp.	Volts.	Amp.	Temp.
137	.003	22° C	130	.015	52° C	137	.006	30°C
164	.006	22	150	.040	52	153	.008	30
207	.017	22	175	.100	52	172	.014	30
			199	.33	52	206	.054	30
Current Reversed, Aluminium now Cathode.								
68	.380	22	51	.59	52	63	.462	30

The voltage lost in the cell resistance was roughly determined in each case by reversing the current. (The aluminium then became the cathode and acted like other metals.)

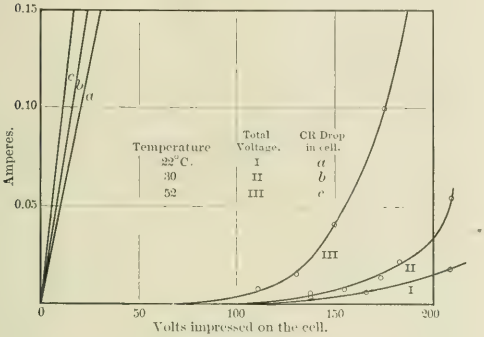


FIG. 2.—CURVES SHOWING THE EFFECT OF TEMPERATURE UPON ANODE RESISTANCE.

No correction was made for the two or three volts lost in decomposing the solution. The curves, given in Plate I., show the *great decrease in resistance of the film* accompanying a slight rise in temperature. For an increase in temperature of 10° C. the resistance of the film at 140 volts is decreased nearly one-half, so that the current is nearly doubled. This large temperature on the resistance does not occur with aqueous solutions or with metals. Aqueous solutions would decrease in resistance from 20 to 30 per cent for a rise of 10° Centigrade, while metals would increase 2 to 4 per cent in resistance for the same temperature change. Solid salts and fused salts possess, however, this enormous temperature coefficient. They decrease in resistance about 100 times for a rise of 50° C., or their resistance decreases one-half for about 7° C. rise. This is very nearly of the same order of magnitude, as the change in resistance for the film with equal rise in temperature. But this is not the only analogy to the resistance of solids.

The actual specific resistance of the film is of the same order as that observed with other solid electrolytes. Special experiments were made to obtain the minimum current at 100 volts with an aluminium electrode with an effective area of 200 sq. cm. The steady current at 25° C. was reduced to 0.002 ampere.

$$R = \frac{E}{C} = \frac{100}{0.002} = 50{,}000 \text{ ohms.}$$

Resistance per square centimeter of aluminium surface = 10,000,000 ohms. Since the thickness of the film at this voltage is about 0.0001 centimeter, therefore the specific resistance per cubic centimeter is

$$100{,}000{,}000{,}000 \text{ ohms} = 10.0 \times 10^{10} \text{ ohms.}$$

This resistance is what was expected. It is over a million times greater than the specific resistance of concentrated aqueous solutions of electrolytes.

SPECIFIC RESISTANCE OF THE FILM FORMED WITH SULPHATES.

The leakage on the direct current[9] with sulphate solutions has been determined by a number of experimenters. The data given by Beetz, Streintz, Wilson, Naccari and others is not sufficiently satisfactory to quote here. The currents observed were rather large. Several sources of error explain this. High temperature, impure electrolyte and incomplete formation of the film, all cause large leakage currents.

The best data has been obtained by Lecher, König and Cook. Lecher using a 10 per cent alum solution, obtained at 10 volts a current density of 0.00013 (and less) amp. per sq. cm. König used a saturated alum solution at room temperature. At 10 volts, the leakage current was 0.000005 ampere per sq. cm.; and this increased to 0.000017 ampere per sq. cm. at 20 volts. Cook also obtained his data with an alum solution. His work is summarized in the following table. The current density is given in ampere per sq. cm.

Temperature.	1° C.	23° C.	48° C.	58° C.
10 V	.000005	.000012	.000029	.0011
20	.000016	.000040	.000076	.002
30	.000029	.0008	.001	
40	.000152			
50	.002			

At 10 volts and 23° C., the leakage current is .000012 ampere per sq. cm. So the resistance offered to a direct current by a square centimeter of aluminium surface amounts to nearly a million (800,000) ohms. Assuming the film has a thickness of 0.0001 cm., then the specific resistance calculates out as 0.8 x 10^{10} ohms per cubic centimeter. This is less than that obtained with phosphates.

The dried film has a resistance (no longer asymmetrical) of this same order of magnitude. Wilson showed that a film formed on an aluminium anode (effective area 53 sq. cm.) in sulphate solutions had, when dried, a resistance 10,000 ohms at 16 volts. Wilson put the aluminium anode with its dry film in mercury and measured the current. The resistance per square centimeter of aluminium surface calculates out as 530,000 ohms.

The temperature coefficient of the film formed with the sulphates is large. It follows the logarithmic law and so great is the decrease in resistance with increase in temperature, that the effect of change in thickness of the film is hardly noticeable. This leads to an explanation of critical voltages.

CRITICAL VOLTAGES.

The critical voltage is the maximum voltage which an electrode will stand without breaking down. The critical current density is the current density at the critical voltage. Critical conditions exist when a slight increase in voltage and current cause so much additional heating of the film as to overbalance the cooling effect completely, and thus all control is lost of the current, since the resistance decreases as a logarithmic function of the temperature, while the cooling effect increases merely as a linear function of the temperature. Aluminium anodes are always hot near the critical voltage, even if they are immersed in an ice cold electrolyte. Beetz made special note of this heating effect, but Lecher tested it in the best way. He put a thermometer inside a hollow aluminium electrode and found the temperature to be above 80° C. at the critical voltage in alum solution. Any means of increasing the cooling effect will raise the critical voltage. By internal cooling of the aluminium anode, Fischer has raised the critical voltage with sulphate solutions from 20 to 220 volts. Additional evidence in great plenty might be cited in support of this resistance theory of critical voltages.

DIELECTRIC STRENGTH.

The insulating power of the film depends upon its thickness.

[9] On alternating circuits Wippermann (1898) found from current and voltage curves of an aluminum rectifier with sulphate solution that there is seldom more than 70 per cent of the current rectified.

A film formed at 100 volts must be capable of insulating the aluminium to that extent. If the dielectric strength of solids and liquids is directly proportional to their thickness, 100 volts would pierce mica 0.00005 cm. thick; glass 0.0004 cm. thick, or oil 0.002 cm. thick. On this basis, the dielectric strength of the film formed with phosphates is nearly as good as mica. To pierce one centimeter of the film would require 1,000,000 volts. The dielectric strength of films formed with sulphates is much smaller than that formed with phosphates.

Specific Inductive Capacity.

This property is fundamental to the well-known aluminium electrolytic condenser. High discharge potentials, due to this condenser effect, have been observed by a number of experimenters; Tait (1869), Beetz (1875), Slouguinoff (1878), Streintz (1887), Pollak, Graetz (1896), Dina (1898), Naccari (1901), Isenberg (1903) and Cook (1904). The best experimental work yet published on this point is that obtained by Cook. But all this data is of no use for determining the magnitude of the capacity. The following is a summary of the important data bearing on this point.

Tait (1869) observed that the polarization of an aluminium anode in sulphuric acid is quick to decrease. Krieg (1886) made observations of equivalent effect as regards aluminium electrodes in a sodium chloride solution. But already, in 1883, Oberbeck had measured with alternating currents the capacity of various metals in this electrolyte (sodium chloride). Oberbeck obtained values as follows:

Silver	0.60	micr.	per	sq. mm.
Gold	0.30	"	"	"
Palladium	0.27	"	"	"
Platinum	0.18	"	"	"
Aluminium	0.05	"	"	"

Oberbeck calculated the thickness of the dielectric for an equivalent air-condenser; but he used "microfarads per square millimeter," instead of "microfarads per square centimeter," and so his calculated thickness is one hundred times too small. The small capacity of aluminium, and the consequent thicker dielectric was explained by Oberbeck as due to a layer of oxide or hydroxide on the aluminium surface. The thickness of the dielectric for the air-condenser equivalent to the aluminium condenser should be .000000001768 cm. Streintz (1888) gives the first numerical data on the capacity of the aluminium electrolytic condenser using high voltages with dilute sulphuric acid solution. The time for discharging the condenser was roughly observed and from this the capacity calculated out as 1 to 3 microfarads per sq. cm.

In 1897, considerable work was published on the aluminium condenser by Malagoli, Haagn and Pollak. Malagoli obtained current and voltage curves[10] of the aluminium condenser on alternating circuits. Haagn observed a capacity effect of nearly one-half microfarad with aluminium electrodes in sulphate solution. Pollak wrote an interesting paper for the French Academy of Science, but he gave no numerical data. The work thus started led to a great deal of additional investigation.

Wilson (1898) found a capacity of 0.15 microfarads per sq. cm. in sulphate solutions near the critical voltage. Mitkiewicz (1901) obtained with a 7 per cent solution of sodium carbonate, a capacity of about 0.2 microfarads per sq. cm. Franchetti (1901), following the work of Andrews on aluminium electrodes in potassium sodium tartrate, found at 87.5 volts, a capacity of 0.058 microfarads per sq. cm. Campbell (1902) has noticed that with increasing voltages the capacity decreases. Trowbridge and Wolcott (1902) have observed at 1.5 volts that the capacity of the aluminium electrolytic condenser is of the same order as that obtained with other metals in sulphate solution. This result was to be expected in view of Scott's work.

Scott (1899), working in Nernst's laboratory, produced an especially valuable piece of research on electrolytic condensers. He measured the capacity of various metals, including aluminum both as anode and cathode. With hydrogen polarization on aluminium electrodes, he found a capacity of 10 to 15 microfarads per sq. cm. As anode, the capacity decreases greatly with increase in voltage.

Capacity of Aluminium Anode.

Volts.	Micro. per sq. cm.
0.0	8.8
0.64	5.73
1.07	4.81
1.75	3.76
0.0	3.72

Scott obtained at higher voltages capacities still lower, even below 0.05 microfarads per sq. cm.

Nodon (1903) claimed a capacity of 1 farad per sq. cm. for the aluminium electrolytic condenser; but 1 microfarad must have been meant, since he calculates the thickness of an equivalent air-condenser as 10^{-8} cm., that is, of the molecular order.

Zimmerman (1904) says: "The electrostatic capacity of 110-volt aluminium condensers may be said to be roughly ¼ to ½ microfarad per square inch of aluminium plate in the cell."

This summary of work done gives a good idea of the difficulty of obtaining reliable results, results that can be duplicated. The curve on Fig. 3 shows how rapid the decrease is in capacity with increase in voltage for sulphates.

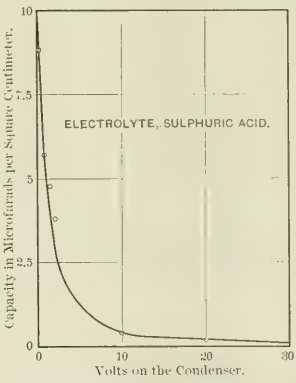


FIG. 3.—CAPACITY OF THE ALUMINUM ELECTROLYTIC CONDENSER. (DATA GIVEN BY SCOTT.)

Calculations can now be made relative to the specific inductive capacity. The standard capacity formula is:

$$C = K \frac{S}{4\pi d}$$

where C is the capacity in electrostatic C. G. S. units, K is the specific inductive capacity, s is the area in square centimeters, and d is the thickness in centimeters. One electrostatic unit of capacity is equal to 1.11×10^{-6} microfarads.

The following table will be found convenient for reference. Capacity per square centimeter is given for different thicknesses and different dielectric constants.

Thickness	Dielectric Constant. 1	10	100
.000001 cm.	.0884	.884	8.84
.00001	.00884	.0884	.884
.0001	.000884	.00884	.0884

Of these three dielectric constants, it would seem comparatively easy to select the best one.

A dielectric constant of one is easily ruled out as not acceptable. Even with the ordinary electrolytic condenser, the analogy to the air condenser does not hold. Under certain conditions platinum may show a capacity of over 5000 microfarads per sq. cm. The thickness of an equivalent air condenser would be 1/200 of the diameter of a hydrogen mole-

[10] Similar work has been done by Wilson (1898 and 1902), Fessenden (1899), Mayrhofer (1900), and others. The main fact established was the formation of a leading current. The best work in this direction is that of Mr. C. L. Zimmerman. (See Trans. Am. Electro. Soc., Vol. V, page 147, 1904). Capacity effects have been observed in connection with the aluminum electrolytic rectifier. Most of the current and voltage curves obtained in this connection show capacity effects, as has been pointed out by Burgess and Hambuechen. See also the work of Wippermann and Grisson.

cule. Such results cast discredit upon the ordinary theory of electrolytic condensers. The problem is more complicated than generally assumed, since it is the meeting ground for atomic, molecular, electrical and optical phenomena.

In the case of the aluminium electrolytic condenser the dielectric film is known to be composed of substances which never give dielectric constants as low as one. A large content of water and hydroxyl radical tends to give a high dielectric constant to the film. If the film were altogether water, the maximum limit of the specific inductive capacity would be 80. The data given by Scott and Wilson on the sulphate would indicate a high dielectric constant. Zimmerman, apparently, favors the high values of the dielectric constant.

In a tentative way the author favors a value of order of magnitude of 10 which he considers "fairly satisfactory." The chief support given this value was found in the following calculations. The capacity of aluminium in phosphate solution was found equal to .013 microfarads at about 100 volts. The thickness of the dielectric film was assumed equal to .0001 cm. From this, value of $K = 15$.

Many difficulties due to *incomplete formation* or *over-formation* of the film make calculations of the dielectric constant unreliable. There is also a strong possibility that the film is a complex structure in which the real dielectric layer is thinner than the total film. Again, the effect of forming the film at different voltages and in different electrolytes must have some effect upon the specific inductive capacity.

In conclusion, the exact determination of the dielectric constant must be made with detached films.

Summary.

Specific resistances have been obtained of the films that form on aluminium anodes in phosphate solutions and in sulphate solutions as respectively 10.0×10^{10} ohms per cu. cm., and 0.8×10^{10} ohms per cu. cm. at about 25° C. The specific resistance of the solid film decreases as a logarithmic function of the temperature. This leads to a definition of what critical voltage and current really mean, *i.e.*, the voltage and current at which the heating effect can be just balanced by the cooling effects. Critical voltages may be raised hundreds of per cent by increasing the cooling effect. This may be done by using cold electrolyte, by vigorous stirring of the electrolyte, and by internally cooling the electrode. A position is thus reached of mathematically treating the phenomena of critical voltages.

The dielectric strength of films formed with phosphate solutions calculates out as 1,000,000 volts per centimeter.

The specific inductive capacity of the film has been calculated and discussed, with the result that while a value of 10 is, tentatively, considered "fairly satisfactory," yet a great deal more reliable data is required for an unqualified statement.[11]

The theory of film resistance that has been developed in this paper for aluminium anodes can probably be applied with equal success to electrodes of other metals, such as Mg, Cr, Bi, Pb, Cu, etc.

[11] The author anticipates that such data will be furnished by Mr. C. I Zimmerman, who has done so much valuable work on the aluminium electrolytic condenser.

A Laboratory Course in Industrial Chemistry.—An interesting paper on this subject, by Dr. William H. Walker of the Massachusetts Institute of Technology, is published in the *Technological Review*, vol. VI., No. 2. Dr. Walker points out that, aside from familiarizing the student with some of those pieces of general apparatus which adapt themselves to reproduction and operation on a laboratory scale, there is not a great deal in a lecture course on industrial chemistry that can be efficiently emphasized by work in a laboratory. Nevertheless, in such a course the student obtains a new point of view—what might be termed the economics of chemistry. A good introductory exercise is the purification of common salt. The influence of the mechanical difficulties inherent in carrying on a given process as contrasted with the cost of raw materials is well shown in the preparation of barium nitrate, etc.

ELECTROLYTIC PRODUCTION OF ZINC AND LEAD FROM COMPLEX SULPHIDE ORES.

By Charles H. Burleigh.

"Refractory zinc sulphides," so-called, may be roughly divided into two classes of ores. First, those ores which are valuable on account of their lead, gold, silver or copper contents, or some mixture of these, together with 7, 10, 12 or more per cent of zinc, and which cannot profitably be smelted. Second, those ores whose values lie chiefly in their zinc contents, but which cannot be profitably distilled, owing to the presence of iron, lead, etc.

These classes blend into each other. In fact, the question of transportation, price of labor or of coal, scarcity of water, etc., may settle into which class an ore should be placed.

In both these classes the usual way of treating them is to separate the zinc sulphides from the other sulphides by crushing and wet concentration, or by crushing and magnetic concentration with or without some roasting, or by a mixture of both methods. When the zinc sulphide crystals are large (coarse crystals) and readily separable, one of these methods is usually satisfactory.

But when the crystals of zinc sulphides are very small and intermixed very intimately with crystals of other sulphides—those of iron, lead, copper, etc., are most common—so that a given piece of ore, 1/50 of an inch in diameter, for example, contains both zinc and other crystals or zinc in chemical union with one of them, as in "Black Jack," it is not possible that any mechanical or magnetic method of separation can be even fairly good. The Broken Hill slimes in Australia and similar slimes in this country are cases in point. A great many mines which have ores carrying zinc, make a class of middlings which carry too much zinc to be smelted, and too much iron, etc., to be retorted at a profit.

In regard to the first class of ores, the problem is to get rid of the zinc, or at least enough of it, so that the balance of the ore can be smelted. The saving of zinc values is a secondary consideration and often a negligible factor.

In the second class of ores, the problem is to save the zinc values and remove the other sulphides as cheaply as possible, saving the last only when it pays to do so.

A method of saving the zinc and lead as pig metal, leaving the gold, silver, copper, iron, etc., with the gangue, to be smelted or otherwise treated as each case demands, becomes of value.

The means employed may be divided into six stages. Crushing, roasting, extracting, filtering, plating lead, plating zinc.

The crushing may be done by Blake crusher, followed by coarse roughing rolls and then by fine finishing rolls, if necessary. The ore must be crushed to such a degree of fineness that it cannot only be properly roasted, but also left in such a condition that the electrolyte, a solution of soda, can reach every particle of zinc oxide and sulphate and lead oxide and sulphate in the ore and bring it into solution. The proper degree of fineness is different in various ores and ranges between 8 and 40 mesh. Excessive fineness—sliming—is not objectionable; usually the finer the ore the quicker the extraction.

The roasting of the ore is almost an art of itself; it is the most difficult part of the process, because zinc ores are not readily soluble in a solution of soda unless properly roasted, and both the character of the ore and the character of the roast have a very great influence upon the degree of solubility. An instance is recalled where the ore, carrying about 32 per cent Zn, 8 per cent Pb, 14 per cent Fe, was nearly "sweet roasted," containing 18/100 of one per cent sulphur. It was impossible to extract more than 46 to 48 per cent of the contained zinc. Another part of the same lot of ore, when roasted hastily down to about 3½ per cent sulphur gave an extraction of 78 per cent. It took nearly ten days to solve this problem and find out why an ore high in sulphur should give a fair extraction, while one low in sulphur gave a very poor one.

This was thoroughly gone into by an eminent mining engineer assisted by some of the faculty of his alma mater. While the investigation was pending a change was made in the manner of firing and the trouble disappeared.

It is useless to expect a good zinc extraction if, during the process of roasting, the ore is made insoluble. It is desirable to roast as much of the ore as possible to an oxide, and leave as much of the remaining sulphur as possible in the sulphide rather than in the sulphate state. A good roast is an absolute necessity; it is at this point that greatest care should be used, because here the greatest obstacles are met with. The quality of the roast determines the percentage of zinc extraction; it determines the extent to which the solution shall be loaded up with sulphate which increases the amount of inert solution and adds bulk without solvent power; and it also determines whether in rare cases of a poor roast, ferrate and ferrite compounds are formed, to give trouble later.

Each ore should be taken as a fresh problem to be solved; once solved, the conditions should be maintained. The order, "Don't touch the air passage, keep the line of red-hot ore up to the seventh door," was sufficient to give a satisfactory product of about 10,000 pounds of well roasted ore daily, for over a month. The furnace used on this occasion was both self-feeding and automatically stirred.

The extraction is accomplished by running the roasted ore into a vat, about 7 ft. diameter and 8 ft. high, containing a hot solution of soda, which is stirred and kept hot until oxides and sulphates of lead and zinc have gone into solution. The time necessary to extract these may vary from 4 to 12 hours. The chemical characteristics and frequently its fineness, have marked influence on the time required for a thorough extraction. Usually practically all of the lead and 80 to 95 per cent of the zinc is extracted.

The filtration of the hot mass is done satisfactorily in a filter press; one with 24-inch x 24-inch plates is a good size to use. The greatest trouble that occurs here is in getting the residue, which is left in the press, free from solution. This residue, which is composed of undecomposed zinc, iron, gold, silver, copper and gangue, is hereafter called "tailings." Frequent washings, while the tailings are still within the press, drive out nearly all of the solution. The extent to which the solution is washed out is determined by the number of washings. The amount of water added to the solution in filtering usually balances that lost through the system by evaporation, etc. Any excess must be concentrated by boiling. The "tailings" from the filter press may in some cases be immediately treated by cyanide to recover the precious metals, in other cases they may be treated by some smelting process.

The solution which runs from the filter press should now contain lead and zinc; this is run into cells which are designed for the plating of lead. The voltage used ranges from about 1.5 volts to 1.7 volts. If the voltage falls much below 1.5 volts, lead plating stops; if it goes much above 1.7 volts there is danger that some zinc may be plated out with the lead, as zinc begins to plate out slowly at about 1.9 volts. If the voltage is kept within the limits, there are no traces of zinc in the deposited lead.

Lead plating gives rise to no difficulties; rich solutions deposit large crystals which often drop off the cathode and fall to the bottom of the cell. As the solution grows weaker in lead, the lead deposited becomes spongy, until finally the lead deposited from a weak solution floats on its surface.

All of this lead, both dense crystals and spongy mass, is taken out of the cell, the solution is pressed out and then it is run into pig metal, of great purity, immediately. In this respect lead differs from zinc; because in less than twenty-four hours after ore goes into the digester, its lead content may be put into pig metal, while zinc may require as many days of plating before the zinc is thick enough to warrant melting up; especially is this true if a low amperage per square foot is employed.

After all of the lead has been plated out of the solution, the latter passes to the zinc cells where that metal is plated out. With a properly designed cell and electrodes—in view of some business and patent matters, it is necessary to use some reticence in matters of description—there is no difficulty in varying both voltage and amperes per square foot within very wide limits. Equally good plating has been done using both 10 and 200 amperes per square foot, and between 2.5 and 7 volts upon a cathode having an area of about 6 square feet. This is about as large a cathode as two men can readily handle after it has been plated until it is about an inch thick.

There are some financial considerations which control within certain limits, the number of amperes used per square foot of cathode surface. These considerations spring from the fact that an increase of voltage accompanies an increase of amperage, so that when zinc is deposited very rapidly, it takes more watts to deposit a pound of it than it does when it is deposited more slowly. To put it another way, it costs more electric power to deposit zinc if five volts are used than it does when two and one-half volts are used. Theoretical current efficiency requires 376 ampere-hours to deposit a pound of zinc. In practice this has been done using less than 400 ampere-hours; in some cases the theoretical efficiency has been approached very closely in practice, and a 95 per cent efficiency has often been attained.

Anodes can be made of several very satisfactory materials; carbon is one of the best of these. Some makes of carbon do not stand well; others, however, do not seem to be affected by the solution and apparently stand indefinitely. The writer uses a specially made anode that has proved to be very satisfactory.

Several metals and alloys are suitable for cathodes. Of these metals, zinc is the best or one of the best, and iron the worst as zinc forms a couple with it. It does not matter much what material is used, as after a few minutes plating you have a zinc cathode, and it continues a zinc cathode until the zinc is stripped off of it. It is, of course, desirable to strip off the plated zinc and use the same cathode again and again. Various kinds of paint have been tried, also lead cathodes covered with graphite and oil, and with a view of causing the zinc to strip off easily; some of these are fairly good ways. The best way, however, is to plate the cathode with a layer of spongy zinc at first, this will take fifteen minutes and the dense reguline metal is then plated on and over the spongy zinc. It is then not difficult to split the plated zinc off the cathode. Of course, in regular plating operations no spongy zinc can be allowed, nor is it.

In regard to the pitting of plates, spongy zinc, and the evolution of hydrogen, on which subject reams have been written, it may not be out of place to suggest that, so far as hydrogen is concerned, there has not been any satisfactory proof advanced that hydrogen is in any way the cause of either spongy zinc or pitted plates. It would be very gratifying to learn how hydrogen in any way, shape or manner affects the face of any plate. My own experience tends to show that hydrogen has no chemical or electrical effect on the plate; by lying on the face of the plate it serves to lessen the cross-sectional area of the liquid conductor and may possibly slightly raise the voltage, but it is not certain that a layer of hydrogen on the face of a plate does any more harm than a layer of inert gas or a layer of air would do under like circumstances.

Hydrogen seems to be a special messenger from the gods of the chemical world—whose mission is to declare: "there is something rotten in Denmark," so far as plating is concerned. When it makes its appearance the conditions must be changed or the plate will go "bad." Hydrogen appears to be an effect, not a cause of poor plating, pitting, spongy zinc, etc., and so far as experience shows is a negligible factor.

The presence of iron in the solution is of vastly more significance. In the first place a small percentage of iron spoils zinc, and in the second place, if it is deposited from the solution, it tends to dissolve any molecule or small particle of zinc

that it touches, by forming an electric couple with it, and when one small particle of zinc is dissolved another may be attacked and then another, till a hole is eaten through the plate.

There are several ways of getting rid of the iron in a solution, but they are all bad from a business standpoint, as they all cost money. The best way to treat the iron question is to keep it out of the solution, which may be done by proper roasting and proper handling of the solution.

The strength of the solution within certain wide limits seems to have but little influence on plating; 25 and 40 per cent of soda plate equally well; when hot, the last-named is very hard on the hands, and is apt to cause trouble, if, as sometimes happens, a leak occurs; however, it dissolves the lead and zinc in the ore more quickly than a weaker solution. With a solution in proper shape and working with a correctly designed cell, the plating of zinc is about the simplest and easiest operation in electrometallurgy.

If a cathode is properly started and let alone till it is taken out, care being taken to keep the cell supplied with plenty of a suitable plating solution, the result will be a dense hard coherent deposit of zinc easily melted, free from oxide, of great purity and having a tensile strength greater than that of cast zinc. When a suitable plating solution is spoken of, one is meant that contains at least 30 mgs. per cc. or about 3 per cent of zinc.

The solution is returned to the extracting vats to treat new ore whenever the zinc content falls below 30 mgs. per cc. It is charged when it contains about 4 pounds of zinc to 10 pounds of soda. This is a good rule to work by, although very strong solutions carry a little more zinc than the rule calls for.

At this point it may well be asked, "How much does it cost to treat a ton of ore by this method? How much will a plant cost? How much does the solution deteriorate? What percentage of lead and zinc are saved?"

The answers will be different for different localities, as labor, materials, power and ores vary. An average price per ton may be, however, put at $8.00 per ton of ore treated under average conditions. Some ores in favored localities, not rich in zinc, can be treated at a cost of $4 to $5 per ton. With richer ores the cost might amount to $12.00 or $15.00 in some localities. Such cases will be very rare.

The average plant which treats ten tons of ore daily will cost approximately from $20,000 to $30,000; in larger plants the plant cost per ton of ore treated would be naturally somewhat less than in smaller plants. The solution, after runs of four, five and eight months' duration, showed no signs of deterioration, and has always plated well, and no better on the first day of the run than on the last day.

As the solution charged with zinc and lead leaves the digester, passing in succession through the filter press, lead and zinc cells and is then again returned to the digester to treat fresh ore, its only source of loss is that of solution lost in the "tailings," which is small and always reckoned as a part of the daily expense.

By this method practically all of the lead remaining in the roasted ore is saved as metal and from 80 to 90 per cent of the zinc—a fair average would be in the neighborhood of 85 per cent.

In preparing this paper it was thought best to omit all generalizations derived from laboratory experiments, and to use only those facts drawn from the writer's experience, which have been tested and proved on a commercial scale.

South Berwick, Maine.

The New York Edison Co. has recently issued a map of New York City, showing the supply network of the Edison Co. in the boroughs of Manhattan and the Bronx. The arc light mains are distiguished from the general service mains for light and power. The company supplies current as far uptown as Two Hundredth Street.

THE MANUFACTURE OF SODIUM BY THE BECKER PROCESS.

By C. F. CARRIER, JR.

In Vol. IX. of the *Monographieen über angewandte Elektrochemie*, in an article entitled "Die Elektrometallurgie der Alkalimetalle," the author, H. Becker, describes a new process[1] which he has devised, and which he states is in practical operation in France in the Usines de Rioupéroux (Isère). The apparatus involved, however (Fig. 1), does not show any remarkable variations from that invented by Castner (Fig. 2). The collecting device D is somewhat different from that of Castner, in that it serves at the same time as cathode. This,

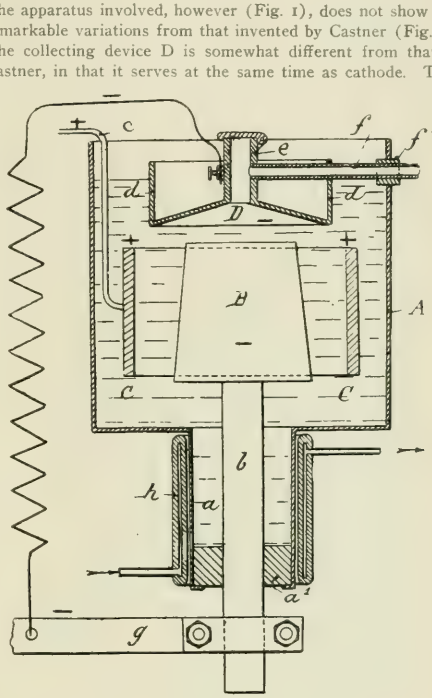


FIG. 1.—BECKER APPARATUS.

as well as the cooling arrangement *h*, may be quite essential precautions; for the process, as is shown later, is carried out at a temperature over 200° higher than that required in that of Castner. The greatest distinction is the absence of the fine mesh wire screen diaphragm which Castner considered absolutely essential to the success of the process, a requirement which this investigation fully substantiates[2]. In the absence of such a diaphragm, the sodium globules will be carried to the anode by the strong currents in the electrolyte, and oxidized. Such a diaphragm has practically no resistance, therefore it would seem that its omission is a very questionable improvement.

Becker states on page 56 of the above-mentioned monograph that his patent covers the preparation of sodium from an electrolyte consisting of sodium hydroxide, to which sodium carbonate or other sodium salt has been added, and refers to U. S. Patent 663,719. Upon reading this patent through, however, one is somewhat astonished to find that the patent only covers the apparatus.

The advantage of the new electrolyte over pure sodium hydroxide should consist in its cheapness. Concerning the proportions in which the mixture is to be made no statement is given, the only hint being that between anode and cathode, at a temperature of 550° C., the electrolyte is fluid, while in

[1] German Patent 104,955, of 1, 21, '99. U. S. Patent 663,719. ELECTROCHEMICAL INDUSTRY, Vol. I, p. 574.

[2] See also Fischer, Zeit. f. Elektrochemie, 7, p. 350 (1900).

other portions of the apparatus it is but partially so. From an example given, the yield can be calculated. An apparatus for using 5000 amperes is said to produce 40 kg. of sodium in twenty-four hours. This is about 40 per cent of the theoretical efficiency, or practically the same as in the Castner process.

A close investigation of the reactions involved in the electrolysis of such a mixture falls far short of clearing up the theory of the process. The addition of sodium carbonate to sodium hydroxide is without purpose unless it takes part in the electrolysis and free CO_2 escapes at the anode. Further, the two components must take part in the process in the same proportion in which they exist in the electrolyte, for the inventor proposes to replace the decomposed electrolyte by continuous addition of fresh mixture. If the decomposition does not take place in these proportions, or if only one component is decomposed, the entire process is calculated upon a false premise.

According to investigations of Le Blanc and Brode[3] the electrolysis of pure sodium hydroxide without a diaphragm can never give an ampere-hour efficiency of over 50 per cent, for half of the sodium is recombined by the water produced from the union of OH ions at the anode. With pure sodium carbonate, however, a theoretical yield of 100 per cent would be

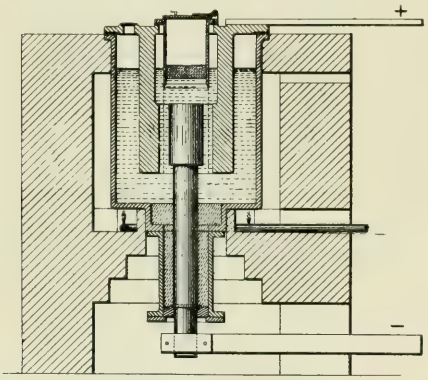


FIG. 2.—CASTNER APPARATUS.

possible, if no difficulties were introduced by the higher temperature required. If, now, sodium hydroxide and sodium carbonate are both decomposed the yield might be expected to lie between 50 and 100 per cent, but by the inventor's own example this has been shown not to be the case. This would seem to indicate that the sodium carbonate takes very small part in the electrolysis.

Starting from another point of view, the same conclusion may be reached. According to new determinations by Lebeau[4], the dissociation pressure of sodium carbonate at 700° is 1 mm. Hg.; at 730° it is 15 mm. and at 880° it is 10 mm. Inasmuch as the partial pressure of the CO_2 in the atmosphere is about 0.2 mm., it is quite probable that at 550°, in absence of moisture, sodium oxide would unite with the CO_2 to form carbonate, rather than that sodium carbonate should be decomposed. For the formation of sodium hydroxide the water vapor comes into play: $Na_2CO_3 + H_2O \rightleftarrows 2NaOH + CO_2$. Even in the presence of water vapor, however, it is not certain that any considerable quantity of NaOH can exist at 550° (see Dammer). Just as doubtful is the possibility that CO_2 can be freed from a molten mixture of sodium hydroxide and sodium carbonate. This is only possible when the absorption capacity of the electrolyte is smaller than the rate of production of the CO_2. The following investigation was, therefore, undertaken to clear up these uncertainties.

[3] Zeit. f. Elektrochemie, 8, p. 717 (1902).
[4] Compt. Rend., 137, 1255 (1903).

Starting with pure sodium hydroxide, a series of mixtures was made by successive additions of sodium carbonate, the electrolysis being carried on continuously. These melted mixtures showed the properties of a solution of two substances which do not build mixed crystals, that is, they give two melting-point curves which cut each other at a eutectic point (approximately 255°). The object of this research, however, was not to fix these curves, so the temperatures determined in Table I. are not the true solidifying points but are the points at which one component had separated to such an extent that the electrolyte was no longer fluid enough for practical use. This point was naturally not sharp, but the approximate temperature was noted and the electrolysis carried out at that, or at a somewhat higher temperature, the anode gas being tested for CO_2.

The apparatus consisted of a cast-iron kettle 15 cm. wide and 10 cm. deep, for containing the electrolyte, the electrodes and means for collecting the anode gas. The electrodes were made of 1 cm. nickel rod, the anode being surrounded by an iron bell for collecting the gases, and both dipping 3 to 4 cm. into the electrolyte. The gas was passed through barium hydroxide solution to test for CO_2. The current density was 0.66 ampere per sq. cm. The results of the first series are shown in Table I.:

TABLE I.

% Na_2CO_3.	Temp.	Volt.	Amp	Remarks.	
16.6	265	7.0	4	No CO_2.	No Na above 280°
23.1	255	8.4	6	"	" 285°
28.6	265	8.0	6	"	" 280°
33.3	270	9.0	8	"	" 290°
37.5	285	7.8	8	"	" 310°
41.2	300	7.8	8	"	" 325°
44.4	310	7.5	8	"	" 345°
47.4	330	6.9	8	"	" 380°
50.0	350	6.1	8	"	" 430°
52.4	390	6.0	8	Temperature less sharp	
55.5	430	5.8	8	Na freed up to 480°.	
56.5	475	5.8	8		
58.3	510	5.7	8		
60.0	550	5.7	8	Na up to 550° but very little. No CO_2 throughout.	

The separate mixtures were prepared by successive additions of carbonate during the progress of the electrolysis, at least fifteen minutes being allowed before the addition of fresh material. The current was passed for over six hours, but during the entire period not a trace of CO_2 was to be detected. It is also to be noted that even at somewhat higher temperatures Na may still be obtained, if that temperature is held as nearly as possible to the melting point of the mixture, although finally the yield decreases. This shows that Castner's observations concerning the electrolysis of pure sodium hydroxide hold also for higher temperatures when a mixed electrolyte is used.

Inasmuch as Becker states 550° as the temperature involved in his process, a second series of mixtures containing a high percentage of carbonate was prepared (and the current density increased to 1.5 ampere per sq. cm. The temperatures given in this and the following experiments are the temperatures at which the electrolysis was carried out:

TABLE II.

% Na_2CO_3.	Temp.	Volt.	Amp.	Remarks.
60.0	550°	5.1	20	Little Na. No CO_2.
62.9	580	5.0	20	Not entirely fluid at 550°.
62.5	550	6.0	20	More Na, but no CO_2.
60.6	480	5.8	20	Electrolyte hardly fluid.
50.0	440	5.7	20	No CO_2. Time, 1 hour.
50.0	480	6.0	20	No CO_2. Time, 45 minutes.
50.0	550	—	20	No CO_2. Time, 30 minutes.

The total time was 3 hours, but no CO_2 was detected.

A further increase in the current density and the percentage

of carbonate did not alter the result. Current density, 2.5 amperes per sq. cm.[5]

TABLE III.

% Na_2CO_3	Temp.	Volt.	Amp.	Remarks.
60.0	580°	—	30	Little Na. No CO_2.
62.5	620	—	30	Less " "
64.7	630	4.3	30	No " "
66.6	630	—	30	No " "

This last mixture was still partly fluid at 600°, but in the presence of the atmosphere the sodium is oxidized or redissolved as fast as formed. The electrolysis was discontinued at the end of one hour.

The escape of CO_2 into the atmosphere could be greatly facilitated by passing a strong current of air free from CO_2, through the electrolyte in the vicinity of the anode. This was accomplished by means of the arrangement shown in Fig. 3.

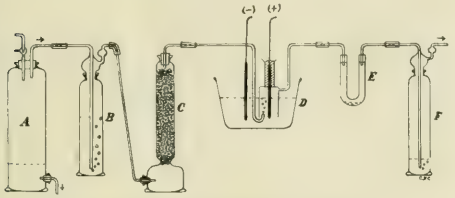


FIG. 3. ARRANGEMENT OF TEST.

A is an air blower; B contains concentrated H_2SO_4; C contains soda-lime; D is the container for the electrolyte; E serves to retain any particles mechanically carried over, and F contains barium hydroxide solution to detect any CO_2. To remove all excess of water the ingredients were strongly heated for two hours before mixing. The results were as follows:

TABLE IV.

% Na_2CO_3	Temp.	Volt.	Amp.	Remarks.
50.0	530	3.6	20	Time, 15 min. No CO_2.
53.7	560	3.8	27	Time, 20 min. No CO_2. Some Na.
57.1	550	3.8	27	Slight precipitate in F.
61.1	530	—	27	Solid salt on bottom of D.

At the end of two hours and forty minutes, a very small quantity of barium carbonate had formed in the wash bottle F. This amounted to 0.28 gram, a yield of 0.13 per cent, but it is more probable that the large volume of air forced through was not absolutely free from CO_2, or minute portions of the electrolyte may have been carried through the tube E.

With the somewhat high potential used in Series I. and II., it is not impossible that double decomposition took place, the iron bell or the containing vessel acting as a bi-polar electrode, in which case the anode gas would contain more or less hydrogen. Even if this were the case, the results would still be of value, for it can hardly be assumed that every trace of CO_2 would be recombined. Further, above 400° any admixture of hydrogen such as would result from double electrolysis makes itself evident by an explosion, a point quite forcibly impressed upon the author in an experiment not here described.

Notwithstanding, it was decided to make another series of experiments in which any double electrolysis would be absolutely impossible. This was accomplished by cutting off the bottom of the anode bell and substituting nickel screen for the impermeable portion removed. The apparatus was also arranged so that the volume of gas evolved at the anode could be measured and compared with a gas coulombmeter in circuit with it. The current density was about 0.5 ampere per sq. cm. Results are shown in Table V.:

[5] The current density at the anode in the Castner process is about 1.64 amp. per square centimeter. (ELECTROCHEMICAL INDUSTRY, Vol. I, p. 15).

TABLE V.

% Na_2CO_3	Temp.	Volt.	Amp.	Time.	cc. Coulomb meter	cc. Anode gas.	% yield
38.8	300	4.8	10.0	4′	490	155	95.1
38.8	325	4.7	9.3	4′ 30″	480	154	90.3
52.7	500	3.4	10.3	4′	495	65	39.4
52.7	500	3.4	10.2	4′	485	67	41.6

Specially noteworthy is the 55 per cent decrease in the yield of anode gas at the higher temperature. This would seem to indicate the formation of sodium peroxide, a circumstance which could not help but have an unfavorable influence on a process carried out at 550°.

Again no CO_2 was to be detected. An analysis by means of pyrogallol in a Bunte burette showed the gas to be over 95 per cent oxygen. The remaining gas was probably nitrogen, as the sample was taken only fifteen minutes after the operation was started, a time insufficient to enable such a comparatively weak gas current to fully expel the air.

Finally, an experiment was made which bears upon this subject, although indirectly. Will CO_2 be given off by the electrolysis of a solution of sodium carbonate in the presence of sodium hydroxide? Fig. 4 shows the arrangement of the apparatus used. The anode consisted of a nickel plate with

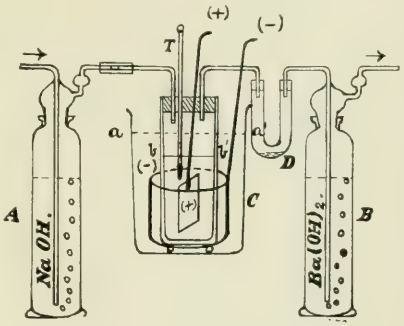


FIG. 4.—ARRANGEMENT OF TEST.

16 sq. cm. of active surface, which was contained in a porous cup. The upper portion of the cup was made air-tight by coating with japan down to the line *b b′*. A strong current of air was drawn through by suction. The figure readily explains the other portions of the apparatus.

(1) The anode compartment contained 100 cc. of 2*n* Na_2CO_3. Temperature, 90° to 97°. Current, 10 amperes. Precipitate began to form in the wash-flask B at the end of 2.5 minutes.

At first glance this time seems a little long, but it has been shown by Kuester and Grueters[6] that bicarbonate is formed in a pure solution of carbonate under the slight partial pressure of the atmospheric CO_2.

(2) The anode compartment contained 95 cc. of 2*n*. Na_2CO_3 + 5 cc. of 2*n*. NaOH. Current, 9.3 amperes. Temperature, 90° to 96°. First precipitate after 4.5 minutes.

(3.) The anode compartment contained 90 cc. of 2*n*. Na_2CO_3 + 10 cc. of 2*n*. NaOH. Current, 9.2 amperes. Temperature, 90° to 95°. First precipitate after 6.5 minutes.

From this it will be seen that the presence of 5 cc. of 2*n*. NaOH increases by two minutes the time required to produce the first precipitate. This is equivalent to 0.4 gram of NaOH. To neutralize this quantity of sodium hydroxide requires as much CO_2 as would be freed by 965 ampere-seconds. In the above cases 1116 and 1104 ampere-seconds were used within two minutes, which is equivalent to 0.HOg NaOH. In other words no CO_2 was evolved until all the sodium hydroxide in the anode compartment was neutralized.

[6] B. B. 36, p. 745 (1903).

Conclusions.

Between 260° and 630°, and with current densities not greater than 2.5 amperes per sq. cm., no CO_2 was obtained by the electrolysis of mixtures of sodium hydroxide and sodium carbonate, in which the carbonate content was increased to 66 per cent. From this we must conclude that the Becker process, as described by the inventor, cannot be carried out, and that inasmuch as only sodium hydroxide is decomposed, it is nothing more or less than an inferior Castner process. Also from water solutions of sodium carbonate containing sodium hydroxide, at a temperature of 90°, and a current density of 0.6 ampere per sq. cm., it is impossible to obtain CO_2 by electrolysis until all the hydroxide is neutralized.

Institute of Physical Chemistry and Electrochemistry of the Technische Hochschule in Karlsruhe, Germany.

GERMAN BUNSEN SOCIETY.

Report of the Ninth General Meeting in Bonn.

By H. Danneel, Ph. D.

(*Concluded from page 315.*)

On the Formation of Glasses.

Prof. Tammann, of Göttingen, presented a paper on this subject. He divides all substances (aside from the old classification into solid, liquid, and gaseous) into isotropic (or amorphous) substances and anisotropic (or crystalline) substances. To the former class belong all substances except crystals. The transition from the amorphous to the crystalline state is of special importance in the production of glass. This transition depends upon two factors: (1) upon the number of nuclei of crystallization, and (2) upon the rapidity with which the single crystals grow. With suitable apparatus the number of nuclei of crystallization can be counted, and it was found by such counting that in nearly all substances the number of nuclei increases as over-cooling is increased.

A curve drawn with the number of nuclei as ordinate and the degree of over-cooling as abscissæ is convex towards the axis of abscissæ; that is to say, the rate of increase is accelerated. At a certain temperature (generally about 100° below the melting point) the curve has a maximum, and then sinks, becoming again convex to the axis of abscissæ. The rapidity of crystallization also depends upon the temperature; it increases with rising temperature, then remains constant for a while, and later decreases. The speaker discussed the details of these phenomena, and the influence of heat of crystallization upon the curves; this heat may produce a considerable rise of temperature. If amorphous sodium silicate is heated to 500°, it suddenly crystallizes, and at the same time the temperature rises by about 160°.

The possibility of working amorphous substances, such as glass, is determined by the dependence on temperature of the three properties: number of nuclei of crystallization, rapidity of crystallization, and viscosity. In the range of temperature in which glass is worked the number of nuclei must be very small, and the viscosity must not increase rapidly with the temperature. One hundred and fifty-three substances were investigated as to their ability to form glass. Fourteen per cent could be but slightly under-cooled; the rest to a greater extent. Thirty-eight per cent could very easily be obtained in the state of glass; besides these, glass is easily obtained from many silicates, phosphates, vanadinates, sulphides, oxides, and from some of the non-metallic elements. In organic substances, the ability of forming glass depends upon the constitution.

The properties of substances do not change at the transition from the liquid to the amorphous condition, but undergo extraordinary changes at the transition from the amorphous to the crystalline condition. This seems to be especially the case with the internal energy, for amorphous substances have a greater energy of reaction than crystalline ones.

Slags.

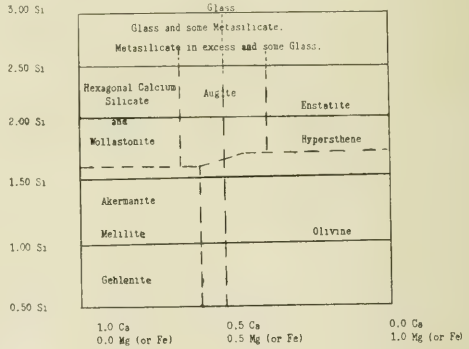
A paper on the origin of the slags in metallurgical processes, the constitution of slags and their industrial utilization, was presented by Prof. Mathesius, of Charlottenburg. He divides slags into (1) oxides or sulphides of metals, which are returned to the metallurgical works for the sake of winning the metal contained in them, and (2) those which are applied for other purposes, or are treated as rubbish. The former are mineralogically identified as spinells; the latter form the subject of the present paper.

Among the silicates the following used to be formerly distinguished: Subsilicates, $9RO.3SiO_2$; singulosilicates, $6RO.3SiO_2$; sesquisilicates, $4RO.3SiO_2$; bisilicates, $3RO.3SiO_2$; and trisilicates, $2RO.3SiO_2$. It has recently been shown, however, that in reality only the orthosilicates $6RO.3SiO_2$, and metasilicates, $3RO.3SiO_2$ exist, and that the other substances are combinations between the base and the orthosilicate, or between silicic acid and the metasilicate. The spinells are formed only when the basicity is very high. Fused mixtures of silicates have recently been treated in detail in an excellent book by Vogt, of Christiania.

The relations here existing are best seen from the accompanying diagram, in which the abscissæ is the composition with respect to bases, and the ordinate is the degree of silicization.

Vogt's Table of the Silicates.

Time of solidification, about one hour.



The most important slags at present are those from the iron smelting furnace, above all, Thomas slag, on account of its valuable contents of phosphorus.

As for utilization, the silicic acid slags are used chiefly for the manufacture of Portland cement. Enormous quantities of blast furnace slag are produced; in Rheinland, for instance, there are iron works which yield up to 3,000,000 kilograms of blast furnace slag per day. In the days when wood charcoal was used, the slag could be used directly as building material, because it offered great resistance to atmospheric influences; but now the slags from the coal furnaces are thrown upon the rubbish heap. After the worthless slags have fallen to pieces, that which has remained intact is picked out and is used in building roads.

In recent times the rest of the material has also been successfully put to use in various ways. At first the so-called Puzzolan cement was made from it, but this turned out not to have much tenacity; more recently the basic slags have been loosened with superheated steam, mixed with Portland cement, and sold as Portland cement; a practice to which the Portland cement factories object with good reason.

A further application of the slag is made by mixing it with dust from the furnace top and re-introducing it into the blast furnace. Finally, as concerns the Thomas slag, its importance

in agriculture is well known; the difficulty due to the injury to the health of those engaged in pulverizing it has now been overcome by the invention of modern crushing mills.

SESSION OF SATURDAY MORNING, MAY 14.

A report was presented by the Committee on Units. A new determination of the gas constant R is to be made. The old Mohr liter, which is still used by some factories, instead of the true liter, should be definitely discarded and forbidden.

ON HYLOTROPY.

Professor W. OSTWALD, of Leipzig, presented a paper on this subject. He gave first an interpretation of the phase rule, differing somewhat from the ordinary one. The conception of "phase" and that of "constituent" are usually considered as equivalent. But the definition of a "constituent" is not quite certain; and the speaker shows that this conception can be entirely avoided.

The new formulation of the phase rule can best be shown by some examples. When only a single substance, for instance, water, is present, then from any phase any assigned coexistent phase can be produced. When, however, several substances are present, as in the case of a solution, where it is customary to speak of two (or more) constituents, then any assigned phase cannot be produced from only a single other one, but several phases must be taken. In every case it can be determined experimentally how many phases are necessary to produce any assigned phase; and the number of necessary phases replaces in the phase equation the number of "constituents." The rule thus takes the following form: The number of co-existent phases necessary to produce any phase whatever, plus the number of degrees of freedom is equal to the number of phases actually present in the system, plus two.

The speaker discusses further the difference between so-called pure substances and solutions. A difference between the two can be observed only when one phase is formed from another, as in distillation or crystallization. In such a process there are two possibilities: (1) the remainder may be unchanged and retain the properties which it had at the start of the process, as in the case of distillation of pure water or pure alcohol; or (2) the remainder may become different from the original fluid, as in the case of the distillation of solutions. The speaker calls the first class of substances hylotropic.

A further distinction of two cases can now be made. The first of these cases is exemplified by the so-called "acids of constant boiling point," which, when temperature and pressure are kept constant, yield a distillate of the same composition as the original fluid; but if the pressure or temperature is varied, the distillate takes on a different composition from the residue (the "hylotropy" disappears). The second case is exemplified by pure water; pressure and temperature can be varied, and yet the distillate remains the same as the residue. But even this case has limits as to the choice of temperature and pressure, for at very high temperatures dissociation of the water takes place, and substances of different composition from that of the residue are obtained.

Finally, substances which remain hylotropic under all experimental conditions that we can produce, are to be called elements. Thus the chemical element is defined as a substance which retains its hylotropy under all conditions; and the difference between elements and compounds lies, not so much in the ultimate nature of the two classes of substances, as in the extent to which they possess a certain quality—hylotropy. From this point of view Prof. Ostwald treats the law of constant proportions and of combining weights; he shows that these conceptions can be defined without using the atomic hypothesis. He emphasizes the fact, however, that this is in no manner a disproof of the atomic hypothesis, but merely goes to show that it is not indispensable.

A discussion of this paper took place, in which Van't Hoff, Nernst, and Roozeboom took part.

ELECTROCHEMICAL REDUCTIONS.

Prof. K. ELBS, of Giessen, in a paper on stereochemical obstructions in electrochemical reductions, stated that in the electrochemical reduction of nitrochinolines in alkaline solution, ana-nitro-o-toluchinoline behaves differentely from ana-nitro-p-toluchinoline and ana-nitro-m-xylochinoline. The former gives azoxy- and azo-derivatives, while the two latter give the corresponding aminochinolines. This phenomenon is independent of the potential, and the ring nitrogen atom has no influence. Azo-substances are always obtained in the electrolytic reduction of aromatic mono-nitro-compounds with nickel cathodes in alkaline solutions; for the direct products of reduction, nitroso-aryl and aryl-hydroxylamine rapidly condense in the presence of alkali to azoxy-compounds, and the reduction remains in the azo-series.

Exceptions occur in the case of o- and p- nitro-amines, and the o- and p- nitro-phenoles, of which the nitroso- and hydroxylamine- derivatives change into chino-derivatives, which are reduced to amines.[1] The disappearance of the nitroso-aryl accounts for the fact that a series of o-nitro-azo-compounds do not yield any poly-azo-compounds; as soon as the nitro group here is reduced to the nitroso group, and the azo group to the hydrazo group, condensation to phentriazoles occurs.[2]

The cause of the abnormal behavior of some nitrochinolines, however, must be looked for elsewhere; it can be accounted for by a "stereochemical obstruction." Prof. Elbs explained this stereochemical obstruction in detail.

In the discussion which followed, Dr. Anschütz stated that reactions with stereochemical obstruction have been found also in purely chemical experiments. Salicylic acid is attacked by phosphorus pentachloride; but if some other radical stands near to the OH-group, then it is no longer attacked. Further discussion, by Goldschmidt, Elbs, Ostwald, and Löb, took place.

ON THE CATALYTIC ACTION OF CYANOGEN IONS.

A paper on this subject was presented by Prof. BREDIG, of Heidelberg. In the presence of cyanides, benzaldehyde condenses very rapidly to benzyl benzoate: $2C_6H_5COH = C_6H_5COCHOHC_6H_5$. Measurements of the velocity of reaction showed that with reference to aldehyde the reaction is of the second order, that is to say, when the temperature and the quantity of potassium cyanide are constant, the velocity is proportional to the second power of the concentration of the benzaldehyde:

$$\frac{dx}{dt} = k.(a - x)^2$$

where a is the original concentration of the benzaldehyde, x the quantity decomposed after t minutes, and k is the constant of velocity. During the reaction the quantity of KCN does not change. The velocity is proportional to the concentration of the KCN; but the KCN may be replaced by the cyanide of any other alkali, provided only it is as much dissociated as KCN. From this it may be concluded that the catalytic action is exerted, not by the KN itself, but by the cyanogen ion.

If the number of cyanogen ions is diminished by the addition of other substances, such as silver chloride, then the velocity of reaction becomes very much smaller. The speaker gives a formula for the reaction, by the addition of a cyanogen ion to benzaldehyde, a nitrile of mandelic acid is produced at first, which reacts with the aldehyde still present, forming benzyl benzoate and reproducing the cyanogen ion.

In the discussion which followed, Dr. Bodenstein called attention to the fact that in Prof. Bredig's experiments, which were made in a solution in alcohol (60 per cent), the conditions are the same as in solutions in water; that therefore the

[1] Elbs, Zeitschr. f. Electroch., 7, 133-138; 141-146 (1900).
[2] Elbs and Keiper, Journ. Phys. Chem., 67, 580-584 (1903).

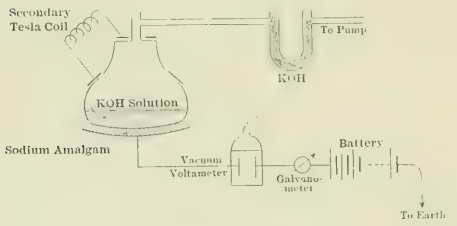
applicability of the theory of solutions to such mixed solutions is proved by these experiments.

Contribution to the Chemistry of Cathode Rays.

A paper on this subject was presented by Dr. E. Bose, of Göttingen. According to the electron theory the phenomena at the cathode in electrolysis consist in the freely movable negative electrons passing out of the cathode and then producing chemical reduction. If this view is correct, the introduction of negative electrons in any other manner ought to produce a similar effect; such introduction of electrons can be effected by exposure to cathode rays. Dr. E. Bose, of Göttingen, set himself the problem of ascertaining whether the action of the cathode rays follows Faraday's law.

The experiments are quite difficult; they have first given the qualitative result that the action of the cathode rays is always one of reduction, as would be expected. Since the experiments had to be carried out in a rather high vacuum, ordinary solutions could not be used, on account of their high vapor tension. Concentrated sulphuric acid or phosphoric acid are not suitable, because the phenomena at the cathode are not simple enough; not only hydrogen, but also other products of reduction appear at the cathode. Dr. Bose, therefore, used concentrated potassium hydroxide solution, in which the phenomena at the cathode consist *only* in the generation of hydrogen.

In order to avoid any influence of the metal submerged in the solution, the investigation was carried on in a vessel which contained no metals whatever. The apparatus was arranged as follows: A vacuum discharge tube of the form shown in the figure, designed to give the electrolyte in its bottom a large



ARRANGEMENT OF APPARATUS.

surface for small volume, was provided at the top with two metal rings, which were connected with the secondary of a Tesla coil. The vessel stood upon a platinum plate; sodium amalgam was placed between the plate and the vessel. From the platinum plate, connections were made through a vacuum voltameter, a galvanometer, and a battery of 3000 volts, and then to the earth; the battery serves to draw the negative electrons more easily through the glass walls of the vessel. At the top of the vessel is a tube which leads to the pump. An oxyhydrogen voltameter with large electrode surfaces and concentrated potash solution under low pressure was used. With such a voltameter, currents of a millionth of an ampere can be measured when the duration of the experiment is not too short. The Tesla transformer was especially simple; its primary coil contained inductance and capacity at the same time. When the experiments were made, the plate at the bottom of the vessel was charged to + 3000 volts, so that the high resistance of the glass could be more easily overcome.

Much more gas was always found than corresponds to Faraday's law, and a very great deal of oxyhydrogen mixture appeared; but this is not surprising, because water vapor is dissociated by the discharge and by the high temperature. An equilibrium of dissociation between H_2O, H_2 and O_2 is reached, but is changed by pumping, so that more of the oxyhydrogen mixture is obtained as the pump is worked more frequently. But, even if the mixture is permitted to explode, still more hydrogen is obtained (sometimes twenty times more) than in the voltameter. The explanation of this observation leads to a conclusive means of deciding between the two opposite hypotheses regarding the chemical action of cathode rays.

According to Wiedemann and Schmidt the cathode rays produce a true chemical effect; for instance, when sodium chloride is exposed to the rays, a subchloride Na_2Cl is formed. On the other hand, Abegg assumes that the action of the rays produces only a physical change. Now the cathode rays represent in the first place an electric current, which undoubtedly has an electrochemical reducing action; further, the cathode rays consist of electric corpuscles of the order of magnitude of 1/1000 to 1/2000 of a hydrogen atom, and possessing a velocity of 22,000 to 50,000 kilometers per second. From this we can compute the kinetic energy of the cathode rays which carry one coulomb of electricity, as 5.45 calories. Let us now assume that the electrons falling upon the fluid are able to shatter a molecule (we may suppose that what is produced by destruction of the molecules of the solid salt, on account of the high frictional resistance, cannot diffuse out, and thus escapes detection). Then we can make the following calculation, if we assume that the heat necessary to disintegrate a molecule is equal to its heat of formation:

The cathode ray which produces electrochemically 0.116 cubic centimeters of hydrogen, has sufficient energy to produce by the disintegration of water molecules 1800 cubic centimeters of hydrogen and the corresponding quantity of oxygen. Of course, most of the mechanical energy is transformed into heat, but the calculation furnishes an explanation why so much more oxyhydrogen mixture is formed than hydrogen itself. If it is taken into account that oxygen, on account of its great solubility and for other reasons, is easily retained in the liquid, then the excess of hydrogen is explained over what would be formed according to Faraday's law. Indeed, it can be established experimentally that the oxygen is held back. From all this it appears that the prospects of confirming Faraday's law for cathode rays are not very good at present.

In the discussion Prof. Nernst remarked that Warburg found that the production of ozone by electric discharges is much greater than would correspond to Faraday's law.

On New Luminescence Phenomena.

Dr. Trautz, of Freiburg in Baden, read a paper on this subject. It is well known that many reactions which take place in the cold are accompanied by the production of light. This occurs especially frequently in the oxidation of organic substances. Also during the crystallization of certain substances a bright illumination takes place. The intensity of the light is proportional to the velocity of reaction, or of crystallization. A larger number of experiments showing luminescence were described. A very pretty lecture experiment is the following: A mixture is made in the cold, of 35 cc. of 35 per cent formaldehyde, 35 cc. of 50 per cent solution (in water) of potassium carbonate, and 35 cc. of 10 per cent solution of pyrogallol. If, then, 50 cc. of 30 per cent hydrogen peroxide are quickly added, the whole fluid glows brightly and boils over.

Fourth Session. Saturday Afternoon, May 14.

The papers presented at the fourth session related exclusively to the application of physical chemistry and electrochemistry to physiological subjects.

Results in Medicine from Freezing Point Determinations.

Dr. Schröder, of Bonn, showed how extremely important physico-chemical measurements have become in medical practice, especially cryoscopic measurements. Blood has a freezing point of —0.56° C., and irregular action of the kidneys is detected in a change of the freezing point of the blood. Dr. Schröder enumerates many other instances in which freezing point determinations may serve, not only in diagnosis, but also more especially as a means of recognizing the normal action of the internal organs of the human body.

DETERMINATION OF THE FREEZING POINT AND CONDUCTIVITY OF URINE, AND PHARMACOLOGICAL RESULTS.

PROF. DRESER, of Elberfeld, showed that determinations of the freezing point and conductivity of urine are especially capable of indicating diseases; often the numerical results obtained show at once the manner in which patients should be treated.

CHEMICAL MASS ACTION IN THE CASE OF TOXINES.

Prof. ARRHENIUS has long been engaged in the study of the chemical explanation of the action of toxines and antitoxines upon each other. It is admitted to be a fact that the cure of poisoning is to be referred to a combination between toxine and antitoxine; but the question arises whether the combination has the character of a chemical compound, or whether it represents a case of absorption. Arrhenius has shown, together with Prof. Madsen, that the reaction between tetanolysine and its antitoxine obeys a simple chemical law—the law of mass action. This furnishes an explanation for the fact that the first dose of antitoxine acts more strongly than the second, the second more strongly than the third, and so forth. The reaction, just like chemical reactions, proceeds only up to a definite state of equilibrium, in the same manner as the reaction between an acid and an alcohol, giving an ester.

Prof. Ehrlich, of Frankfort, has set up the hypothesis that the toxines consist of different substances which have a different avidity (tendency to combine) for the antitoxines; and with this assumption he has attempted to explain the phenomenon. Arrhenius shows that the course of the reaction between tetanolysine and its antitoxine is precisely the same as that between ammonia and boric acid. Ammonia is also a lysine for the red blood corpuscles, and its poisonous effect is overcome by boric acid; and it is doubtless that this reaction obeys the law of chemical mass action.

Experiments with diphtheria toxine are somewhat more complicated, because here the first dose of serum does not work the most strongly, but on the contrary has no effect at all; Ehrlich has therefore made the assumption that the part of the diphtheria toxine which acts first and accordingly has the greatest avidity for the serum, is not poisonous. Arrhenius has repeated these experiments, but has found no indication of such unpoisonous substances, and consequently thinks that Ehrlich's experiments are affected with errors. In similar manner the action of other poisons is discussed. It is interesting that acids and alkalis which tend to decompose the poisons, are effective in proportion to their concentration in H and OH ions.

Prof. Arrhenius made a reply to an article of Nernst's in the *Zeitschrift für Elektrochemie* (vol. 10, p. 377), in which the latter had questioned the applicability of the law of mass action, maintaining that the toxines and antitoxines probably give a case of so-called "false equilibrium." If equilibrium really occurs, then it should be possible, as in other chemical equilibriums, to reverse the reaction by continually withdrawing one of the substances originally present. Since the velocities of diffusion are different for toxines and antitoxines, it should be possible by dialysis to regain the poison from a completely unpoisonous mixture of diphtheria toxine and serum. In reply to all this Arrhenius announces that he has made such experiments; by diffusion through a membrane he obtained from a harmless mixture a liquid containing a deadly amount of poison.

Prof Ehrlich spoke for the point of view that the toxines in the body are held by so-called "receptors," and that the union of the toxine to these receptors takes place with different rapidity for different toxines. If diphtheria toxine is injected into the veins, it is immediately absorbed; drawing off the blood and replacing it by new blood does not prevent death. Snake poison, on the contrary, is absorbed more slowly, so that soon after injection it can be neutralized by antidotes; but later it can no longer be neutralized. Ehrlich thinks that the law of mass action is not applicable, because the toxines unquestionably are not single substances; in generating toxines the bacteria certainly produce several substances.

Prof. Nernst made the objection that the toxines are undoubtedly colloids, for which as yet it has not been possible to demonstrate the existence of any reversible processes at all. The theory of so-called immunity is also opposed to the hypothesis of reversibility.

CONTRIBUTION TO THE THEORY OF ELECTRIC STIMULATION.

Prof. W. NERNST, of Göttingen, presented a paper on the above subject. It is well known that alternating currents of very high frequency of sufficient intensity to produce light from an incandescent lamp can be passed through the body without injury, while a direct current of one thousandth of this intensity is fatal. The reason is because the alternating current has not time to produce sufficient changes of concentration in the cells. From a former research Nernst obtained a formula according to which the change in concentration, which depends upon the current i, is inversely proportional to the square root of the frequency n. This formula was verified at that time for the human body; as an indicator of the effect produced, the feeling produced by the alternating current in passing through the hand, was taken. In order to make conclusive tests, a pure sine-current must be used, or at least a machine ought to be employed which always gives current curves of the same wave form. In the present experiments Nernst used an alternating-current generator, of special design, the terminals of which were connected to a nerve and muscle preparation from a frog. One end of this preparation was fastened firmly, while the other was connected to a pointer, by which motions could be detected very accurately. The voltage of the generator was gradually increased, and then the intensity of current noted at which the first muscular contraction appeared. The test always lasted only a short time, so as to avoid fatigue effects. Before each experiment the electrical resistance of the muscle was measured. In the following table V gives the voltage, n the frequency, and i the current, as observed and as computed from the formula $i = C \sqrt{n}$ micro amperes.

V	n	$i \times 10^{-6}$, observed.	$i \times 10^{-6}$ computed.	Difference in per cent.
0.66	105	0.81	0.78	− 4.2
0.66	136	0.88	0.92	+ 4.6
1.68	485	2.16	2.21	+ 2.3
1.68	960	2.41	2.47	+ 2.9
2.24	2230	3.85	3.73	− 3.1

In consideration of the difficulty of the measurements this must be regarded as a very good agreement, and it must be concluded that the square root law holds for all frequencies between 100 and 2000.

Some experiments were made with a "singing arc," but it was found not to give a uniform alternating current. It is therefore not suitable for this research; still less suitable are the oscillatory discharges of Leyden jars, so that the experiments of Einthoven (Pflüger's Archiv., vol. 82, p. 101) are of an accidental character.

Prof. Nernst remarked that by these experiments an electrical myth as tenacious of life as the sea serpent, had finally been killed; namely, the belief that electric currents flow only upon the surface of the human body. This is also improbable on account of the high resistance of the body.

NEW MEMBERS OF THE AMERICAN ELECTROCHEMICAL SOCIETY. —At the meeting of the Board of Directors, held in Philadelphia on August 5, the following gentlemen were elected members of the Society: Joseph Clark, Jr., Stanley, Idaho; Benito Herrera, Los Angeles, Cal. At the September meeting of the Board of Directors, the names of the following gentlemen will come up for election: F. E. Schmitt, New York; James G. Marshall, Niagara Falls, N. Y.; Timothy C. Root, Buffalo, N. Y.

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By George P. Scholl, Ph. D.

Electric Furnaces and Furnace Products.

Process of Smelting Compounds and Producing Carbides.—W. S. Horry, Niagara Falls, assignor to Union Carbide Co., Niagara Falls. Patent 765,838, July 26, 1904. Application filed April 13, 1904.

W. S. Horry, the well-known inventor of the rotary calcium carbide furnace bearing his name, outlines in this patent an improvement in the manufacture of carbide by the use of alternating currents. He has found that it is not only advantageous to employ an alternating current for the manufacture of carbide, but that the current efficiency is a function of the current frequency. A frequency of 25 alternations per second is inferior to that of 50 alternations, as patented some years ago by Willson. One of one hundred and twenty alternations gives a much higher yield than that of fifty, and frequencies above one hundred and thirty-three greater than those given by any commercial machines are still more advantageous. He therefore employs an alternating current of the highest frequency which will not cause undue losses by inductive drop in the current mains. While not fully able to account for the increased yield of calcium carbide due to the use of an abnormally high frequency, he is of the opinion that the molten calcium carbide, as well as the calcium oxide, acts as an electrolyte, and that a direct current or an alternating current of low frequency decomposes both the carbide and the oxide electrolytically, a considerable portion of the energy of the current being wasted in this way, instead of being converted into useful heat. The losses due to such partial electrolysis are stated to be serious on account of the high difference of potential maintained between the electrodes. As a current of higher frequency liberates a smaller amount of ions at each reversal, the anions and cations liberated at the same electrode by the reversal of the current may be assumed to more fully recombine, their chemical energy being transformed into heat of combination. The process is carried out by heating a mixture of finely divided lime and carbon in a Horry furnace with an alternating current of sufficiently high frequency to reduce the losses due to electrolytic decomposition to a practicable minimum. It is stated that while the process has been commercially utilized for the production of calcium carbide, it is obviously useful for the production of other carbides, silicides, etc., and in general for such smelting operations as are effected by heat generated by passing an electric current through the charge, and in which electrolysis is undesirable.

Electrolytic Production of Metals and Compounds.

Manufacture of Brominated Indigo.—Albrecht Schmidt and Rudolph Mueller, Hoechst-on-the-Main, Germany, Assignors to Farbwerke, vormals Meister, Lucius and Bruening. Patent 765,996, July 26.

The bromo-indigo is manufactured by electrolyzing an aqueous or sulphuric acid solution of indigo or indigo white, treated with hydrogen bromide, sodium bromide or other bromates. It is not absolutely necessary to use a diaphragm, as the hydrogen set free by electrolysis has no action in an acid solution on indigo and bromo-indigo. To obtain good yield the acid used must not be too dilute, for otherwise too many oxidation products are obtained, *e. g.*, isatin. Good results are obtained with hydrobromic acid of 40 per cent or more strength, or sulphuric acid of 50 to 78 per cent, containing hydrogen bromide. Concentrated hydrochloric acid may also be used, if sufficient hydrobromic acid is present, but its use in electrolysis is somewhat inconvenient. In carrying out the preparation of the bromo-indigo, finely-divided indigo is stirred with hydrobromic acid of 40 or more per cent strength, to a thin paste, by means of a high-speed agitator. The electrodes are best of carbon, and may be separated by a diaphragm. Hydrobromic acid serves as electrolyte and the electrolysis is carried out at about 2.5 volts and three amperes. Active stirring is kept up during electrolysis until the desired degree of bromination to the mono or dibrom substitution product is obtained. The current density is not stated. The time required to obtain the above products may be calculated from the time of electrolysis and the amperage. The process is the same with indigo white, and the use of a diaphragm is optional. Bromides, such as sodium bromide, may be added during electrolysis. The advantages of the method thus far described are stated to be, first, that only small portions of bromine act on an excess of indigo, as with proper choice of the current conditions no excess of bromine can be employed, and second, that no regeneration of hydrogen bromide is necessary. The brominated indigos thus obtained resemble in their properties those obtained by dry bromination, but whether they are identical with the latter or with the products obtained synthetically, for instance, from indoxyl, could hitherto not be observed.

Apparatus for Vacuously Depositing Metals.—Thomas A. Edison, Llewellyn Park, N. J. Patent 767,216, August 9, 1904. Application filed August 1, 1903.

The apparatus is primarily designed for coating phonograph records, and is an improvement upon the apparatus described in Mr. Edison's patent of November 18, 1902, which is illustrated in Electrochemical Industry, Vol. I., page 219. A vertical sectional view is shown in Fig. 1. Extending through a base plate 3, preferably of glass, are glass tubes 4 carrying circuit wires 5. Electrodes 6, preferably in the shape of thin strips of foil, are depending from the wires, and a small weight 7 at the bottom of each electrode serves the purpose of keeping them flat, as the best results by the most even coatings are obtained when the electrodes are perfectly flat. The electrodes are made of the metal to be deposited, and are preferably of gold, as the latter may be highly comminuted and is of non-oxidizable character. A metal rim 8, within which is placed a glass bell jar 9, serves to make a perfectly tight joint, when filled with molten paraffin. The air is exhausted from the bell jar through pipe 11. Supports 12 within the vacuum chamber carry vertical shafts 13 with tapered ends. Surrounding each of these shafts is a sleeve 14, with hardened bearing cup 15 at the top and a disc 16 at the bot-

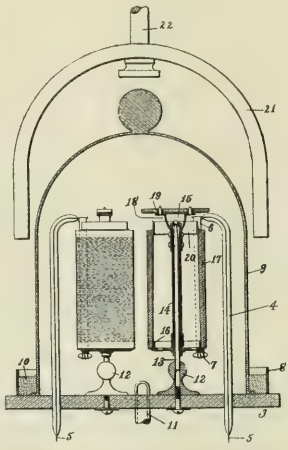


FIG. 1.—APPARATUS FOR DEPOSITING METALS IN VACUO.

tom, which disc carries the record 17, to be plated. Arms 18 extend up from the sleeve 14 and carry a movable armature 19. A guard or shield 20, preferably of brass, fits within the top of record 17 and is intended to prevent the metal from being deposited in the interior of record 17, and to cause it to deposit evenly on the latter's edge with a clear line of demarcation. A magnet 21, carried by a shaft 22, can be rotated by suitable contrivances. Two of the above-described apparatus work together, the current being switched onto them alternately so as to allow the electrodes to cool off. A suitable switch worked by clockwork regulates the switching operation. An induction coil is connected with the electrodes, after a proper vacuum has been created, the discharge being so regulated as to secure between the electrodes a silent or brush discharge, which causes the metal composing the electrodes to be vaporized and to be deposited on the records. The magnets 21 are rotated at the same time, so as to rotate the objects, whereby a perfectly uniform film will be deposited upon them. When the film is of the desired thickness, the bell jars are removed, which permits the coated records to be taken off for subsequent treatment.

STORAGE BATTERIES.

Secondary Battery.—O. H. F. C. Walter, Berlin, Germany, assignor to Pflueger Accumulatoren Werke, Berlin. Patent 766,078, July 26, 1904. Application filed December 1, 1903.

The plate in this battery consists of a grid of vertical and horizontal rods, which are covered in the usual manner with paste and dried. It is then exposed to a temperature higher than the melting point of the metal of which the plate frame is made. In the case of lead, a temperature of from 400° to 500° C. will be required, while for frames of lead and antimony, or lead, tin and antimony, etc., much lower temperatures can be used. By this means the metal forming the framework is fused out. A horizontal section of the plate is shown in Fig. 2 before and after heating. The vertical bars *a*, the horizontal ones not being shown in this section, are surrounded with the active mass *d*, and after heating, only the hollow spaces *d* remain, while a thin porous film *f* is left which holds together the separate parts of the active mass. It is stated to be quite immaterial in this process whether the plate has been treated with current or not before fusing, or whether it is old or new, or whether it is a mass plate or one which has been treated according to the Planté process. The advantages claimed for the plate are great lightness in consequence of the removal of the metal core and great capacity, because the acid reaches the active mass, not only from the outside, but also from the inside, as it penetrates through the porous metallic films *f*.

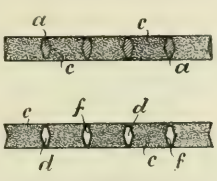


FIG. 2. BATTERY PLATE.

Storage Battery.—F. T. Cable, New Suffolk and Grant E. Edgar, Greenport, N. Y. Patent 766,216, August 2, 1904. Application filed February 26, 1903, renewed December 19, 1903.

The invention relates to storage batteries for use on vessels, especially submarine; the object is to insulate the cells from each other, and the entire battery from the vessel, to ventilate the battery, to prevent the electrolyte from slopping over into the vessel or into other cells, and to provide for the support of the heavy elements of the cells, so as to permit the use of glass, earthenware or hard rubber receptacles. The inventors provide an inner tank which contains the cells, and an outer tank, separated from the inner one by a space, the upper part of which is partitioned off and serves to catch liquid which slops over. A current of air is maintained through another portion of the space between the two tanks, which is partitioned off below the space which serves to catch the liquid. Further details are described in the specification.

Apparatus for Washing Storage Batteries.—J. L. Lough, New York. Patent 766,365, August 2, 1904. Application filed May 17, 1904.

The inventor provides for the washing and cleansing of storage batteries, by arranging two flexible pipes at opposite ends of the battery, the free ends of which extend down to the bottom. The deposit is sucked out by means of a small rotary pump and delivered into a precipitating tank with a baffle, below which the liquid has to pass. The passage of the solution through this tank is rather slow, so that the sediment has time to settle. The clear solution returns from the top of the precipitating tank into the storage cell.

Method of Producing Elements for Electric Cells.—T. Kitsee, Philadelphia. Patent 766,504, August 2, 1904. Application filed April 14, 1902. Renewed June 16, 1904.

The invention deals with the production of electrodes for small cells and aims at avoiding the handling of the separate small electrodes when they are charged up either before or after being filled with active material. It is therefore proposed to assemble a series of small grids by connecting them by lugs, so that the whole forms a mechanical unit. This unit is then charged and after charging is finished, the lugs connecting the various small grids to each other are cut, and the latter then form the finished electrodes for the small cells.

Accumulator.—J. A. Lyons and E. C. Broadwell, Chicago. Patent 766,958, August 9, 1904. Application filed September 25, 1903.

The accumulator shown in the specification consists of a rectangular metallic receptacle with an interior lining of cotton cloth or other material. "An anode plate of graphite platino iridium or other inert substance stands in the middle of the receptacle and is surrounded by a mixture of carbonaceous material such as charcoal, etc., mixed with infusorial earth and the oxide, hydroxide or oxy-salts of such metals as give two or more forms of oxides, such as lead, nickel, cobalt, cerium or the like. This in a pasty consistency is placed around the anode, and the mass is saturated with a solution of either a basic haloid of the oxy-salt or its equivalents of the metal by the electrolysis of which deposition in a reguline state occurs at the cathode. In practice there is preferably used as the electrolytic salt zinc oxy-chloride or zinc chloride or bromide holding zinc hydroxide or oxide, or a zinc oxide bearing salt holding the zinc oxide with weak affinity in suspension or weak chemical solution, although it is evident that the basic sulphate, basic nitrate or any other oxy-salt can be utilized, and also that the oxy or other basic salts of tin, cadmium, copper or the like can be substituted for the oxy-salts of zinc, but zinc oxide or hydroxide must always, if zinc salts are used, be present in excess." The basic compounds are intended to neutralize the acid formed at the anode during electrolysis, and thus to prevent electrolysis of the acid, which would take place if the latter were not neutralized.

Insulated Battery Cell.—V. G. Apple, Dayton, Ohio. Patent 767,323, August 9, 1904. Application filed November 9, 1903.

The battery comprises a metallic containing case, either furnished with interior recesses or with perforations for the purpose of serving as support for the active material and acting as one of the electrodes of the battery. This is intimately united with an exterior coating of rubber, applied to it in such a manner that the two layers form practically an integral structure. The insulating material employed is of such a

nature that it may be applied to the metal in a softened condition and be subsequently treated so as to cause it to harden in close adhesion to the metal.

Galvanic Elements.

Primary Battery.—Thomas A. Edison, Llewellyn Park, N. J. Patent 766,815, August 9, 1904. Application filed November 18, 1903.

The invention relates to the manufacture of copper oxide electrodes for batteries of the Lelande type. Such a cell does not reach its normal discharge rate until the surface of the copper oxide is completely reduced to the metallic state, and the electrode is usually thus reduced before being placed in the cell. Mr. Edison finds that very good results can be obtained by dispensing with this preliminary reduction and rubbing instead ordinary red oxide of copper upon the surface of the electrode. As the electrode is more or less porous, the particles of the red oxide adhere very tenaciously. As the red oxide is easily reducible, the surface reduction to the metallic state progresses rapidly, so that the cell quickly reaches its full discharge rate. The copper oxide electrodes are preferably made by treating precipitated hydroxide of copper with hypochlorite of sodium, thereby producing an excessively finely divided black oxide of copper. This is dried, moistened with a solution of sodium (?), pressed into plates of the desired form and burnt in the regular manner to consolidate the mass.

Miscellaneous

Rectifying and Interrupting Alternating Current.—W. Scheidel, Chicago. Patent 766,468, August 2, 1904. Application filed December 31, 1903.

The apparatus described in the specification is shown in Fig 3. It is intended to be applied to inductoriums and like apparatus, which are operated by a high frequency current. It consists essentially of a vessel of aluminium 6, which when acting as anode prevents the passage of the current, but allows it to pass with but little resistance when acting as cathode. The other electrode 8 is formed of platinum wire, surrounded by a tube of insulating material 10, and projecting through a small orifice in the lower end of the tube into the electrolyte. A holder rod 9 supports the anode. The electrolyte is phosphate of soda or ammonia or other like solution generally employed in rectifier cells. A binding post 7 serves as connection for one of the alternating-current line wires to the vessel. It is claimed that this arrangement is adapted to eliminate to a very material extent the usual rapid generation of heat and increase in temperature in the ordinary form of electrolytic interrupter.

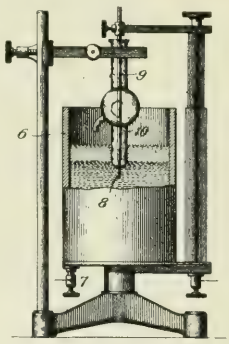


FIG. 3.—ELECTROLYTIC RECTIFIER.

Method of Purifying Water.—W. M. Jewell, Winnetka and W. J. McGee, Oak Park, Ill. Patent 766,146, July 26, 1904. Application filed January 26, 1903.

The invention consists in purifying water by introducing an insoluble reagent in powdered form into it and keeping it suspended by agitation, while subjecting the water to electrolysis at the same time. The reagent which is claimed to be best suited to play the role is barium carbonate, in the form of witherite. When the latter is introduced into a water containing sodium sulphate and electrolysis takes place, the sulphuric anion combines with the witherite to form insoluble barium sulphate, CO_2 being liberated. If the natural water does not contain enough chlorides of calcium or magnesium a quantity of calcium chloride is added, and the carbonic acid gas from calcium or magnesium carbonate leaving sodium chloride in solution, which is said not to be objectionable for most commercial purposes. The apparatus comprises a tank, which carries a vertical shaft, provided at its lower end with a cross-bar, from which depend the electrodes of lead, which are alternately positive and negative. The apparatus is described in detail.

Apparatus for Purifying Water by Electrical Means.—J. S. Zerbe, New York. Patent 767,195, August 9, 1904. Application filed May 2 1904.

The apparatus comprises a vertical electrical chamber containing alternate anodes and cathodes. The water enters at its lower end and passes up through the electrical chamber into a so-called ozonizing chamber above it, which is claimed to act as disseminator for the ozone. From there it is carried by means of a pipe to the lower end of a cylindrical vertical filtering chamber, within which is arranged a perforated shell wrapped with felt or other filtering material. On top of the first-named vessel is a little reservoir designed to catch the ozone, and a pipe leads from it to the bottom of the filtering chamber and into the interior of the perforated shell. The exit for the purified water is located at the top of the filtering chamber. One-half ampere of current per gallon per hour is stated to be generally sufficient for sterilization of the water, the voltage ranging from six to 110. Low voltage is preferable in all cases. Aluminium electrodes are preferred. The outside of the interior shell, which is covered with felt, comes into contact with a brush when turned by a hand-wheel provided for this purpose, and is thus kept clean by the removal of the accumulated impurities.

RECENT METALLURGICAL PATENTS.

Zinc

The reduction of zinc oxide in a blast furnace by means of water gas or natural gas has attracted considerable attention for some time, and a great many experiments have been made. A stumbling block to such attempts has been the great quantity of combustion-gases and nitrogen in the zinc atmosphere, which prevented liquid condensation and resulted only in the production of zinc dust. O. Nagel has formerly patented a process of producing spelter by reducing zinc oxide in a blast furnace by means of water gas. He has now found (U. S. Patent 766,279, August 2), that hydrocarbons in gaseous or gasified condition, including, of course, coal gas and natural gas, are equal and sometimes superior to water-gas for carrying the process into effect.

The inventor states that natural gas containing from 85 to 90 per cent of methane is especially advantageous, as the concentration of zinc vapors obtained is nearly twice as large as with water-gas. He explains this theoretically by the fact that one molecule of methane combines with four atoms of oxygen and one molecule of water-gas only with two. Furthermore, the coefficient of molecular friction of methane is only about half that of water-gas, which fact explains the easy condensation of zinc in a methane atmosphere. For this reason a considerable quantity of nitrogen may become added to

methane without affecting the reducing capacity of the latter as compared with water-gas. Natural gas, with 85 to 90 per cent methane and 2 to 15 per cent nitrogen, occurs very frequently, and is said to be either superior to or equally effective as water-gas for the reduction of zinc.

When such heated hydrocarbons are passed through a zinc ore or preferably a mixture of ore with from 10 to 15 per cent of coal, the zinc oxide is reduced, the hydrocarbons being split up into carbon monoxide and hydrogen. The inventor gives the following formulas for the reversible reactions involved in the action of methane.

(1) $ZnO + CH_4 = Zn + CO + 2H_2$
(2) $ZnO + H_2 = Zn + H_2O$
(3a) $H_2O + CO = H_2 + CO_2$
(3b) $H_2O + CH_4 = CO + 3H_2$
(4) $CO_2 + CH_4 = 2CO + 2H_2$

Equation (1) represents the splitting up of the hydrocarbon. In (2) the reduction is continued, and at increasing temperature the reaction goes, as indicated in the equation when read from the left to the right; the difference of the oxidation heat of ZnO (85,000 calories) minus that of H_2O (58,000) being large (27,000). The water formed in (2) is reduced partly by carbon monoxide according to (3a), and partly by methane, according to (3b). The result of the reaction is an atmosphere practically free of oxygen, oxydizing substances, and nitrogen, thus allowing for an easy concentration of the zinc vapors to liquid metal.

Copper.

R. Baggaley and C. M. Allen (766,654, 766,655, 766,656, August 2) patent a process of producing copper or matte without the need of water concentration and calcining and without the use of carbonaceous fuel, or with only a small percentage of such fuel. They separate the sulphide ores (low in silica and high in matte-making sulphides) from the siliceous ores (high in silica and low in matte-making materials) and use both kinds of ores as follows. The sulphide ores are smelted in a furnace with or without the use of carbonaceous fuel, to produce a low-grade matte high in fuel value, *i. e.*, high in its contents of sulphur, iron, and other oxidizable elements. The matte and slag are discharged from the smelting furnace into the usual forehearth, where the slag is separated from the matte and the matte is then drawn off from time to time.

The matte, free from slag, is then put into a converter and charges of siliceous ore (of smaller quantity than the matte) are added to the bath, while air is blown into the mixture. The blast of air oxidizes the combustible ingredients of the bath—namely, sulphur and iron and other oxidizable elements—and produces within the bath an intense heat; the oxidized iron combines with the silica of the added ore, and forms a floating slag, while the metallic compounds of the added ore are dissolved in the molten bath. The slag is drawn off from time to time, the converter being tipped for this purpose. As the matte loses its iron and sulphur, the volume of the bath decreases, new molten matte is poured in and siliceous ore is added, until the converter has received its full charge of matte, which is enriched to the extent desired, and is then poured either as converter matte or as blister copper.

The slag from the converter, which is necessarily basic, is poured upon the charge in the furnace for melting the sulphide ores and serves there the purpose of dissolving any solid accretions on the walls of the furnace; at the same time it furnishes additional heat. The siliceous ore which is gradually charged into the converter is preheated by waste gases.

R. Baggaley (766,579, August 2) patents a method of sampling plates or slabs of blister-copper. The method consists in casting the copper in plates of uniform size (17 x 24 x 2 inches) and casting on the surface of the plate 240 marks regularly distributed over the surface and indicating the location of the sampling-holes. Two hundred and forty plates of the above size make a carload, and through plate 1 a hole is drilled at mark 1, through plate 2 at mark 2, etc. The cuttings are placed into a sampling receptacle, and when assayed, are claimed to give an accurate and reliable indication of the proportions of copper and precious metals contained in the carload.

Alloy.

R. B. Wheatley (766,085, July 26) patents an alloy of copper and zinc in the proportions found in common brass, but with certain additions intended to increase the tensile strength, the ductility and the resistivity against corrosion by atmospheric influence; it is stated that the alloy may be spun and mechanically manipulated while cold with a considerable degree of deformation without fracture. The alloy consists of 98.5 per cent of copper and zinc (present in the respective proportions of 60 and 40 per cent), the remaining 1.5 per cent being made up of tin, aluminium, iron, manganese, tungsten and strontium.

Lead.

J. H. Mercadier (767,906, Aug. 16) patents a process for manufacturing spongy lead specially intended for storage battery plates. Molten lead is stirred by means of a fork in a receptacle; while it is cooling, it is powdered with a metal oxide, like litharge or minium or oxide of zinc or a mixture of these oxides. When the lead begins to become pasty, the receptacle is placed over a slight flame, and the lead is kneaded by means of a stirrer and continuously powdered with the oxide. When solidification has taken place, the lead is in form of an extremely porous mass, consisting of filaments soldered together and leaving interstices between them. This mass is stated to have great mechanical strength.

Iron and Steel.

Pipes and blowholes in steel castings are due to the presence of gases, and it has been the practice to add some aluminium which acts in a well-known manner. M. Meslans (765,932, July 26) proposes to use an alloy of aluminium and calcium—the aluminium to take care of the oxide of carbon and the calcium of the hydrogen and nitrogen gases. (The manufacture of such an alloy should not be difficult by electrochemical means.)

Scrap-steel containing a small amount or carbon cannot be converted into a high-grade commercial steel without recarbonizing in a furnace. If coke, together with the scrap steel is put into the furnace, the carbon is driven off before the steel is heated to a temperature sufficiently high to absorb the carbon in the coke. H. B. Atha (765,724 and 766,131, July 26) endeavors to prevent this by either of the following two methods. The first is to intimately mix the scrap steel with finely-divided carbon, press the mixture into bundles and treat them in the open-hearth furnace. The other is to put finely-divided carbon in a liquid, place bundles of scrap steel in this liquor, whereby they receive a coating of carbon, and treat them in the open-hearth furnace.

J. W. Arnold (765,158, July 19) patents a process of treating iron and steel preparatory to rolling it into bars. The object is to dispense with the use of dampers, the heat of one charge serving to temper the preceding charge. For this purpose he introduces the fresh, cool charge into the furnace at a point between the fire and the preceding charge, so that the latter heats the former and is itself cooled.

A method of hard-soldering pieces of cast iron (which is said to be also applicable to other metals) is described by H. F. Hiller (767,339, and 767,340, August 9). The pieces of the iron are heated red-hot and allowed to cool; the parts to be brazed are then moistened with a mixture of boracic acid (1 ounce), carmimic acid (¼ ounce), carbonate of lime (¼ ounce), water (1 quart). They are then placed in the forge and heated until they are hot enough to melt the flux, which is then added and which consists of boric-acid crystals. After

the flux has thoroughly entered the joint, a brass-copper spelter is added.

Metallurgical Furnaces.

Two patents were granted to G. H. Shellaberger for details of construction of rotary ore-roasting furnaces. One patent (765,997, July 26) refers to mechanical details of a furnace, the interior of which is divided into a plurality of longitudinal ore-chambers and interspersed heat flues, the ore being fed longitudinally through the furnace body in one direction and returned through other chambers and delivered at or near the same end into which it was fed. While the ore passes through the first chambers, it is subjected to a gentle and gradually increasing heat, so as to get dried before it comes into the actual roasting chambers. The travel of the ore through the furnace is effected by the tumbling action of the ore as the furnace body rotates so that the rate of feed is adjustable by changing the speed of rotation. The second patent (765,998, July 26) refers to a rotary furnace, the interior of which is divided into a plurality of ore-roasting chambers with interspersed heat-flues; the roasting chambers are radially disposed around a common central air-trunk; each chamber is provided with several air inlets, controlled by valves located within the air-trunk. The main air-trunk enters through, and is directly exposed within the combustion chamber of the heat generating furnace.

L. H. Allen (766,156, July 26) patents an ore-roasting furnace of the construction shown in Fig. 1, in which 10 is the revolving ore-roasting cylinder and 33 the furnace; 30 is an annular vaporizing receptacle, supplied through the pipe 41 with water; 34 and 49 are air-blast pipes. During the centrifugal movement of the ore-roasting cylinder 10, water is flowing through 41 into the vaporizing receptacle 30, generating steam. The blast of air through 49 upon the products of combustion on the furnace grate produces a reducing flame of great intensity, which is projected into the ore-roasting cylinder. "The flame affords requisite oxygen for the oxidation of the ores, and the vapor which becomes superheated from the vaporizing receptacle 30 is decomposed, the hydrogen gas evolved uniting with the oxygen in the flame and an oxy-hydrogen flame projected the length of the cylinder, and as at the outward passage the gases and products of combustion are retarded in passing out of the cylinder the overturned ores are attacked by the oxy-hydrogen gas, with which it comes in contact under pressure, the ores being scarified by the heat."

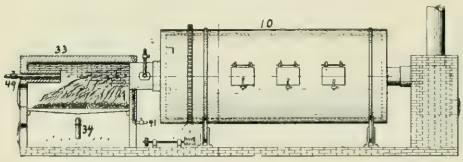


FIG. 1.—ORE ROASTING FURNACE.

L. T. Wright (12,254, August 2) patents details of construction of the rotary stirrer in the McDougall roasting furnace. Since the central shaft, the arms and the rabbles thereon are liable to be disabled by a momentary excess of heat, he provides means for cooling these parts.

J. Reuleaux (767,243, August 9) patents details of construction of a continuous heating furnace, the prime object being to prevent cinders from falling from the slabs or billets into the fuel-ports and lodge therein as well as in the supply chamber.

A patent granted to J. C. Fox (765,728, July 26) relates to the construction of muffles of the kind used by assayers for the roasting or cupellation of ores. If the air is admitted at one end of the muffle, the reaction takes place successively and is completed much earlier in the front of the muffle than at the back. To shorten the time, the inventor provides the muffle with channels or passages through which the air supply can be distributed to all parts of the charge simultaneously. These channels are formed integral with the walls of the muffle.

S. Forter (767,399, August 16) patents a feeding device for gas producers, furnaces, etc., so as to direct the charge both towards the center and the sides. A. Ronay (766,903, August 9) patents a charging device for furnaces, the prime object being to prevent the outside air from entering, or the inside gases from escaping, during the process of charging. The charging device comprises a bent charging tube having a branch connected with the furnace, and a mechanical charging device in another branch of the tube; the arrangement is so that the fuel in the bent elbow portion of the tube closes the same, to prevent the escape of gas and also protects the mechanical charging device from the heat of the furnace.

J. Kennedy (767,285, August 9) patents details of construction of a valve for furnace flues, H. R. Palmer (765,901, July 26) an air-valve mechanism for gas-burning furnaces.

S. V. Peppel (765,789, July 26) patents a method of converting furnace-flue dust into blocks, suitable for treatment in ordinary furnaces. He mixes intimately lime with the flue-dust, adds water and presses the mixture into blocks.

Slime Filtering Apparatus.

G. S. Duncan (766,025, July 26) describes a filtering apparatus for the rapid and thorough separation of gold and silver bearing solutions from finely divided residual ores or slimes. He uses a large number of hollow, flat vertical filters worked under vacuum. They are suspended within the vat containing the material to be treated and each of these filters consists of a skeleton framing covered with filter-cloth; they are arranged comparatively close and parallel to each other with scrapers between. The filters are connected on top with a pipe in communication with a vacuum tank which receives the solutions as they are filtered, while the scrapers are reciprocated between the filters at intervals to remove the muddy coating and carry it below the bottom of the filters and prevent clogging.

SYNOPSIS OF ARTICLES IN OTHER JOURNALS

A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.

Industrial Electrochemistry and Electrometallurgy.

Iron and Steel Metallurgy.—The August number of *Engineering Magazine* contains a long and profusely illustrated article by A. Minet on the application of electric furnace methods in iron and steel metallurgy. The author first makes some general remarks on the cost of power. On the basis of a price of $10.00 for an electric horse-power-year at the electrodes within the furnace, and assuming a year of 8000 hours, he gives the cost of 1 hp.-hour at 0.126 cents, 1 kw.-hour 0.172 cents, and 1000 large calories 0.2 cents (in the formulas given in the foot-note of page 797 there is some confusion in the units, for instance one kg.-meter equals 9.81 joules or watt-seconds, and not watts as stated). The author then gives some general notes on metallurgy of iron in general (among them

the somewhat peculiar remark that "the electric calories furnished by natural power are more economical than the calories set free by the combustion of coal" for roasting purposes). He then gives a review of many electric furnace processes which have been proposed, and nearly all of which have been described at length in ELECTROCHEMICAL INDUSTRY. The author divides all methods into direct methods (starting from the ore and without passing through casting) and indirect methods. Among the direct methods he gives the processes of Stassano, Heroult, Harmet, Keller, Contardo, Ruthenburg and Minet-Neuburger. The latter is illustrated in Figs. 1 and 2, the intention being to operate the furnace either by elec

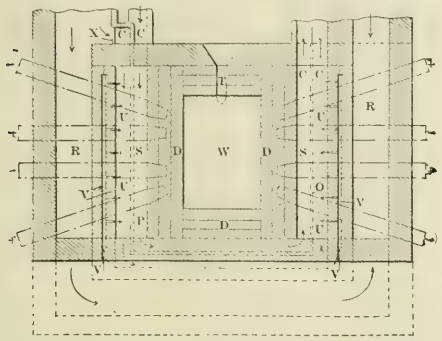


FIG. 1.—SECTION OF MINET-NEUBURGER FURNACE.

tricity or by waste blast furnace gases or by gases coming from gas works. In connection with gas engines driven by the bast furnace gases, and used as prime movers for dynamos, the furnace is intended to insure to iron works the application of most electrometallurgical processes under conditions of economy of the same order as those attained in works driven by natural power.

The furnace consists of a central chamber W, supplied with an outlet hole T, and separated from the heating chambers SSSS by partitions DDD, of which the nature varies according to the reactions and the products of the reactions. The

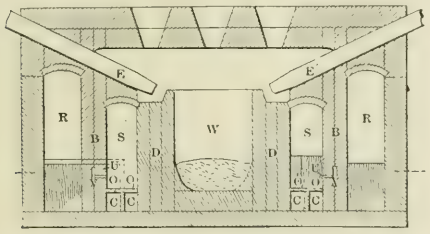


FIG. 2. SECTION OF MINET-NEUBURGER FURNACE.

heating chambers SS receive through the holes OO either blast-furnace gases from the flues CC, or rich or poor gases from the flues C' C' coming from a gas producer or gas works; and these gases burn in the chambers SS. These chambers are separated from other reheating chambers RR by partitions BB, of refractory clay, in which are built flues U opening into the combustion chambers SS by air-holes, V. The reheating chambers RR are traversed by the blast-furnace gases, of which a part enters into the flues CC, which are provided with a regulator X, for controlling the quantity of gas which should pass into these flues. This part burns in SS; the greater part of the blast-furnace gas passes unburned from RR and is used for supplying the gas engines. The electric current is conducted by the electrodes EEE' E', which in the various cases take the positions represented. It is possible also to conduct the blast-furnace gases to the center of the reaction at VV, and to take advantage of their reducing properties or to burn them directly above the raw materials. With a furnace of this kind it is possible to obtain every temperature from 200° to 900° C., by using the blast-furnace gases alone; from 900° to 1,300° by using the blast-furnace gas with other rich gases; and from 1300° to the temperature of the arc, by adding to these different sources of heat the action of the electric current.

The author then goes over to the discussion of indirect methods. He first describes an experiment of Hillairet and Garnier. In a refractory tube are placed end to end a stick of carbon and a rod of iron containing 0.1 per cent of carbon in such a manner that the ends in contact are about the middle of the tube. The whole is heated in a little blast furnace. During the heating a suitable continuous current is passed through the two rods, from the carbon to the iron. At the ends of three hours the iron rod is withdrawn suddenly from the tube, and cooled by immersion in water. The end of the iron rod, which was in contact with the stick of carbon, is hardened to a depth of ten millimeters to such an extent that it scratches glass. By reversing the current in another experiment it is proved that the cementation is due to the transfer of carbon into the iron by the action of the current. In this case the iron rod, through which the current now enters, remains almost unchanged. The author finally describes the processes of Laval, Gerard-Lecuyer, Kjellin and Gin.

Mercury Cathode.—Various attempts have been made to diminish as much as possible the quantity of mercury in the mercury cathode process of electrolyzing alkali chlorides. Gurwitsch has proposed for this purpose to use a vertical or inclined iron plate over the surface of which a very thin film of mercury continually flows downwards. For this purpose he directs streams of mercury from small orifices (of about 1/3 mm. diameter) against the iron plate. The adhesion between iron and alkali amalgam is so great that this thin stream expands into a strip of 25 to 30 mm. breadth. Under the influence of the electric current, however, the surface tension of the mercury would be changed, tending to contract the strip; to prevent this, Gurwitsch provides the iron plate with longitudinal grooves, the capillary action of which withstands the surface tension. W. KETTEMBEIL and C. F. CARRIER, JR., have made experiments concerning the practicability of this method, the two papers being published in the *Zeit. f. Elektrochemie,* August 5. Kettembeil found that it is difficult to amalgamate thoroughly the iron cathodes, and that it is necessary to keep them always under the influence of the electric current. Since the mercury flows downwards with great velocity, it stirs up the electrolyte, so that continually new electrolyte, charged with chlorine gas, gets into contact with the amalgam surface; this means, of course, losses which can only be prevented by using a diaphragm. Even with a porous diaphragm he obtained an ampere-hour efficiency of only 85 per cent, without it only 50 per cent. C. F. Carrier, Jr., succeeded in getting somewhat better results, due to a modification of the mechanical details of construction of the iron plate. The best results were obtained by him with a current density of 0.34 to 0.50 ampere per sq. cm.; the ampere-hour efficiency was then about 90 per cent if a diaphragm was used, and a little over 70 per cent without a diaphragm. From special experiments made for this purpose he concludes that without a diaphragm, a good efficiency can be obtained only if the mercury surface is at rest or moves only slowly and regularly. Gurwitsch's proposition seems, therefore, not promising for use in practice, since without diaphragm the efficiency is too low, while with a diaphragm the voltage is too high and the apparatus becomes too complicated.

Recovery of Tin from Scrap.—An interesting summary of electrolytic processes for recovering tin from tin scrap and

tin slags is given by J. B. Kershaw in *Elec. Rev.*, June 18. Claus used a bath of sulpho-stannate of sodium (sp. gr. 1.070), heated to about 90° C., with a current density of 10 ampere per square foot; the process does not seem to be in use at present. Garcia used a pure hot solution of ferric chloride for dissolving the tin (without the current); the solution of ferric and stannic chloride obtained in this way was then filtered, carbolic acid and sulphuric acid were added and electrolytic deposition of tin was carried out with carbon anodes and lead cathodes; the process was not a success. Gelstharpe used as electrolyte a 1.25 per cent solution of hydrochloric acid, with a small amount of sulphuric acid; tin cuttings in wooden crates were the anodes, tinned sheets the cathodes; the iron remaining after removal of the tin was worked up into crystalline ferrous sulphate. The author believes that none of the processes using acid or a mixture of acids as electrolyte, and producing ferrous sulphate or chloride as a by-product, can hope for permanent success. He then speaks briefly of the process of the Th. Goldschmidt Co. in Essen, which has been commercially very successful. The process is kept secret, but the author believes it to be an alkaline process; sodium hydrate being used as electrolyte, and the tin scrap in iron baskets being the anode. Smith & Guthensohn have patented a process, the electrolyte being composed of dilute sulphuric acid (one in ten) and tin sulphate. The author states that in several works slight modifications of the old process of Beatson are used, in which hot caustic soda solution of 1.21 sp. gr. was employed and the scrap and cuttings were used as anodes in flat boxes having wire gauze sides. Thin iron plates are used as cathodes. In order to refine the tin obtained as a powdery deposit on these plates Beatson pressed it into flat cakes, and employed them as anodes in a second depositing vat, in which a strong solution of stannous chloride or sulphate was the electrolyte, while a revolving cathode of iron or tin was used to receive the deposit, which was brought into a more dense and solid state by a pressure roller. The tin obtained in this way was finally melted and cast into ingots. The author finally gives some estimate of the operating cost; the cost of electric energy is given as $51 per ton of tin, or less than 9 per cent of the present market value of the metal. He concludes that the alkaline electrolytic process for recovery of tin from tin scrap and cuttings is one which is likely to expand into an industry of considerable importance. But the methods of collection and shipment of the scrap to special detinning works are expensive, and he thinks that tin scrap recovery plants should rather be worked as an adjunct of all large electric supply stations. This would provide them with a day load and the plant would only draw on the local supply of tin scrap and cuttings.

Electroplating.—In *Metallurgie*, August 8, W. Pfanhauser gives an illustrated description of the equipment of some modern electroplating establishments. He deals especially with electroplating zinc on iron, and remarks that the electrolytic method is now used in plants which, by size and economy of operation, are superior to plants using the old method of "hot galvanizing." In electroplating iron with zinc often the mistake is made that too thin a layer of zinc is plated. To get a good durable zinc coating, it is necessary to deposit at least 140 to 150 grams of zinc per square meter of surface; such a coating may be obtained within 30 to 35 minutes with a normal current density of 1.5 to 2.0 amperes per square decimeter. If irregular surfaces containing holes, etc., are to be electroplated with zinc, he proposes to first produce a uniform deposit of zinc from an alkaline solution, and to thicken this deposit by using afterwards the ordinary electrolyte consisting of zinc sulphate with the regular additions for the sake of increasing the conductivity.

Electrometallurgy.—In *L'Industrie Electrigure*, July 10, 25, J. Izart begins to give a review of the general status of electric furnace industries. He first discusses the application of the electric furnace in the iron and steel industries, especially for the manufacture of special steels and ferro-alloys. He deals briefly with aluminium, sodium, copper, zinc, nickel and mercury. Concerning the use of electric furnace methods in metallurgy, he thinks that they do not yield a sufficiently pure metal, except when used in combination with electrolytic action, as is the case for aluminium, sodium, etc.; in other cases the electric furnace may be useful as an auxiliary to concentrate the metallic contents of an ore near the mines, to save freight expenses.

Recent Advances in Electrochemistry.—A reprint in full of B. Blount's series of Cantor lectures on this subject (abstracts of which have already been noticed in these columns) begins in the *Jour. Soc. of Arts*, August 12.

Theoretical and Experimental.

Molecular Attraction.—In a paper, published in *Jour. of Phys. Chem.*, June, J. E. Mills endeavors to show that the attraction between molecules varies inversely as the square of their distance apart, and does not vary with the temperature. Considering the attraction as a property belonging to each molecule, or more exactly, as a mutual property of each pair of molecules, it must vary as the mass, large numbers of similar molecules being here considered. In other words, the law of gravitation holds not only between masses, but between the molecules of a substance, and this law is alone sufficient to account for the phenomenon of the internal heat of vaporization. He derives the equation that the ratio of the internal heat of vaporization to the difference of the third root of the density of the liquid and the third root of the density of the vapor should be constant. This law was tested for twenty-one substances and found perfectly correct for eleven substances; with five substances the divergencies found all occur at such points and are of such magnitude that they may easily be due to errors of observation. Stannic chloride failed to agree with the equation. To the associated substances, water, methyl, ethyl, and propyl alcohols, and acetic acid, the equation was not supposed to be applicable; but within wide limits the agreement of these substances, acetic acid excepted, is such as to suggest the conclusion that the molecular association is used by the molecular attraction.

Theory of Solutions.—Another attack on the electrolytic dissociation theory is made by J. Traube, in the *Philosophical Magazine*, August. He first sums up his objections to this theory, and then proposes a new hypothesis, in which he assumes both dissociation and association. He believes that even in the most diluted solutions in one moment every dissociation, for instance, of a molecule NaCl, is followed by an association of Na and Cl. There will be a chain of dissociations and associations, and not only a series of dissociations. "The calculation of the coefficient of dissociation is the undisputable merit of Arrhenius, but the interpretation of that coefficient we should certainly reject." According to Traube, the Arrhenius coefficient of dissociation represents "the relation of the number of particles of the electrolyte which are joined with 2, 3, etc., single molecules of the solvent and the number of its particles which are joined with one molecule of the solvent or none." He thinks it is not improbable that even at the moment when the ions are joined, every ion takes hold of its particle of the solvent, excepting in stronger solutions, where it will occur that 2, 3 ions of one molecule of them have only one single molecule of the solvent at their disposal. He applies his views to the relation between conductivity and dilution.

Porous Diaphragm.—A new form of diaphragm—or rather diaphragm support—for electrolytic cells is described by F. Mollow Perkin in a Faraday Society paper, published in *Electrochem. and Met.*, July. Cells, as shown in Fig. 3, are made of wedgewood ware or of some glazed material; in the figure the small cells are of wedgewood and the larger are salt-glazed. The actual cell consists of two portions, one fitting within the other. Thus, in the figure, where two cells are

shown, the smaller one in each case fits into the larger one. Each complete cell consists of two perforated cells, the perforations being about large enough for a pin of ordinary size to pass through; the inner or smaller cell fits loosely into the larger one. When put together, a liquid can pass readily through the complete cell, which thus, of course, does not act as a diaphragm. In order to use the cell as a diaphragm the inner cell is, for example, wrapped tightly with asbestos

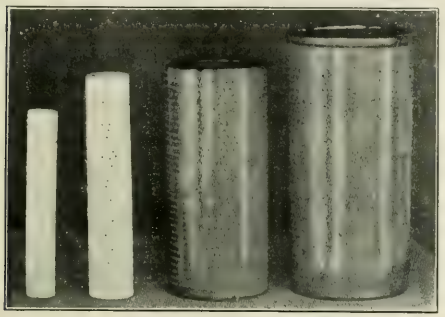


FIG. 3.—POROUS DIAPHRAGMS.

paper until it can just be passed down into the outer cell. The asbestos should be wrapped in such a manner that there is considerable overlapping at the bottom end. This is then folded over so as to practically make a bag, and when pushed home the inner cell rests tightly upon the asbestos. The cells are made so that about three folds of thin asbestos paper is sufficient to cause the one part to fit tightly into the other. The diaphragm so prepared is soaked in water or the electrolyte, such, *e. g.*, as sulphuric acid or a salt solution, and is then ready for use. When carefully packed this makes a very efficient membrane, since the two portions of the cell are, owing to the perforations, to all intents and purposes, open to the passage of the current. For most purposes, for sulphuric acid which is not stronger than 25 to 30 per cent, or for moderately strong caustic alkali, and, of course, for neutral solutions, it is not necessary to employ asbestos, ordinary filter paper making a very effective diaphragm. Parchment can also be used, or a pulp of asbestos poured into the annular space between the two cells, or a pulp of blotting paper, or coarse sand or coarsely powdered glass. Asbestos or a pulp of well-washed nitrated cotton wool can well be used even with strong acids or alkalis.

Formation of Ozone.—It is well known that with increasing temperature the stability of endothermic compounds increases. It should, therefore, be expected that at a very high temperature oxygen is changed by heat partly into ozone according to the equation $3O_2 = 2O_3$. J. K. CLEMENT has made a series of careful experiments in this direction at temperatures above 2200° C. and has found that the expected result is not obtained. His paper is published in *Annalen der Phys.*, IV. Folge, Vol. 14, 1904, page 334. He conducted a stream of pure oxygen over the surface of an incandescent Nernst filament, so that it was heated to about 2200° C., while, when streaming away, it was quickly cooled. He could not detect any formation of ozone, nor was any found at the temperature of the electrolytic arc lamp, about 3000° C., nor in experiments with a hollow Nernst filament. Whenever there were traces of nitrogen present, NO_2 was formed, which, in its reactions is very similar to ozone; and it seems to be due to this fact that former investigators thought that ozone had been formed. From Clement's researches it seems certain that the only case in which ozone is formed at a high temperature, is under the influence of the electric spark; but it is possible that in this case the formation of ozone is due solely to the action of ultraviolet light. The author also gives the results of extended researches on the speed of disintegration of ozone; on the basis of a formula of van't Hoff which can be applied to this case, he finds that at 1000° C. the content of ozone decreases in 0.0007 second from 1 per cent to 0.001 per cent; this means that if ozone is really formed at a temperature of 2200° C. or more, it must disintegrate almost instantaneously when cooled even very quickly.

Mixed Indicators.—A contribution to the theory of indicators is given by M. SCHOLTZ in the *Zeit f. Elektrochemie*, July 29. If there are several indicators simultaneously in hydrochloric acid solution, and if the solution is being gradually neutralized by caustic potash, the strongest acid will first change color, and only after a further addition of caustic potash the weaker indicator acid will change color. By observing the order in which the indicators change color, it can be determined which of the indicators is the stronger acid. As a proof of the reliability of this method, the author mentions the fact that out of 120 experiments which were made with twenty-two indicators in various combinations, there are not two which would contradict each other. The results of his experiments are given in form of tables.

Internal Friction of Solutions.—In the *Zeit f. Elektrochemie* of July 15, G. RUDORF refers to former experiments made by him, in which he believes to have found a negative value of the internal friction in certain solutions. From more recent investigations of Fawsitt, he concludes there is an error in his former measurements, due to the spiral form of capillary tube used by him. His former conclusion of the existence of a negative internal friction is now considered by him as unwarranted.

Manganese Analysis.—A quick electrolytic method of determining manganese with the use of a revolving cathode is described by J. KOESTER in the *Zeit. f. Elektrochemie*, July 29. He uses a dish of platinum-iridium as anode, while as cathode a platinum plate is used, revolving at a speed of 600 to 700 revolutions. The electrolyte (about 110 to 130 cc.) contains, besides the manganese salt (not the chloride), 5 to 10 grams of ammonium acetate, 2 to 3 grams of chrome alum, and 1 or 2 cc. alcohol. The voltage at the terminals may be about 7 for a current density of 4 to 4.5 amperes. Before the circuit is closed, the solution is heated to 75° C. and the burner is then removed. Should the temperature rise beyond 85° C. during electrolysis, some cold water is added.

Laboratory.—In the *Zeit. f. Elektrochemie*, July 15, E. COHEN describes the equipment of the new van't Hoff laboratory of physical and inorganic chemistry at the University of Utrecht. The same issue contains the speeches held at the opening of the laboratory. Van't Hoff received the honorary degree of M. D.

BATTERIES.

Accumulator Construction.—With reference to the paper of W. W. Donaldson, abstracted in our June issue, p. 245, S. H. RABENALT makes several remarks in *Elec. World and Eng.*, June 18. He thinks it is not a right principle for the construction of a Planté plate, to provide only for good electrical connections, and to hope that the mechanical will take care of themselves. The Planté positive plate has a tendency to grow and buckle, and he advises to construct such a plate of a large number of small "units," comprising the "active portion" of the plate and to weld these into a solid and rigid frame of antimonial lead; each section or unit should be joined to the frame at its upper edge only, and be allowed to follow its tendencies to expand or grow in three directions, sufficient space being provided for this purpose. Negative plates of the Planté type are neither ideal nor even desirable; batteries with Planté negatives give an exceptionally high c. e. m. f. on charge and are very susceptible to "treeing." After discussing several other points, the author speaks decidedly against Donaldson's argument that the grooves should be tightly filled in order to maintain contact between the grid

and the active mass. The fact that a groove is tightly filled will not prevent the formation of additional peroxide if condition favors a tendency for it. If the grooves are so tightly filled that they are unable to accommodate additional mass, the mass will make itself the necessary space. If the frame construction (which encloses the active portions tight, not providing for expansion space) is made out of soft lead, the plate will grow and buckle. If the frame construction is made out of antimonial lead (with a comparatively high percentage of antimony) the plate will very often crack or break.

Care of Storage Batteries.—In the London *Elec. Rev.* of July 22, an anonymous writer points out that batteries often fall into a bad condition simply on account of the bad treatment they have received. He speaks especially of the length of charge which should be given to a battery. He thinks that heavy overcharges are very deleterious to a battery. He, therefore, recommends to base the length of a charge on the number of ampere-hours taken out during the previous discharge, allowing a certain constant percentage excess. For any type of grid, the percentage excess of ampere-hours required to fully charge it is fairly constant irrespective of the discharge rate, and it is, for ordinary purposes, safe to fix this at a figure depending on the average ampere-hours efficiency, at rates which can be considered normal under the different circumstances of each case. This may be anything between 8 and 12 per cent. For this purpose the ampere-hours charge and discharge should, of course, be metered. He recommends to book the ampere-hours charge and discharge each day with the final closed-circuit voltage at the end of discharge, while hydrometer readings should be booked once a month, but taken once a week.

Storage Battery Records in Telephone Practice.—An article on this subject by H. S. Knowlton is found in *Elec. World and Eng.*, July 23. The removal of the local open circuit battery from the subscriber's station, and its replacement by the storage battery at the central office has greatly simplified the maintenance problem. Under the new conditions the breakdown of a battery at a central energy office would be a serious matter, and every possible precaution should be taken to avoid such a contingency. The author thinks one of the best methods of forestalling battery troubles is to keep a daily record accurately prepared and neatly filled in of the charging and discharging conditions, voltage, specific gravity and appearance of the cells. He describes in detail how to arrange and how to keep such records.

Lead Poisoning.—In the *Centralblatt f. Accum.*, July 1, T. Umbach states that the usual method of cleaning the hands with ordinary soap and water after having handled lead compounds is not sufficient to prevent lead poisoning. To prevent it successfully, the lead should be changed into sulphide, which is absolutely without danger to the organism. Blum recommends the use of "akreminine soap," which produces the change into the sulphide directly on the skin. (Wien. Med. Wochenschrift, No. 13.)

Miscellaneous.

Phosphorus.—An editorial in the *Metal Industry*, August, deals with the "abuse of phosphorus." It is said that the true function of phosphorus and alloys is not generally understood. Its real function is the reduction of the oxides of copper or tin, which are always found when these metals are melted, and phosphorus itself is not intended as an ingredient of the alloy. Up to a certain amount, phosphorus is a benefit in various alloys, but beyond that it acts as a positive injury. The amount necessary in phosphorus bronze is a quantity just sufficient to reduce the oxides present, and such an amount is rarely over 0.05 per cent. Contrary to the usual belief, the amount of phosphorus should decrease rather than increase, as the proportion of tin is increased. Leaving out the question of the use of scrap, it will be found for rolling mill work—*i. e.*, plates, bars or rods not in metal moulds—that 0.05 per cent of phosphorus is the proper amount, and under no consideration should more be added. For sand castings it will be advisable to use more phosphorus than that employed for rolling mill work. This is on account of the use of so much scrap, the phosphorus of which is oxidized out by repeated meltings. In order to allow for such oxidation, the excess of phosphorus is introduced. Were nothing but new metal used, 0.05 per cent of phosphorus (as given above) would be ample. If the usual run of sand casting work is made, and the material in the form of gates, risers, bad castings, etc., is repeatedly melted, then an amount of phosphorus equivalent to 0.25 per cent should be introduced. In connection with the large amount of phosphorus which is often recommended in alloys for sand castings, the writer states that in every case he has found that blow-holes were present in the castings. The user of phosphorus bronze should not introduce it in form of stick phosphorus, but in form of phosphor tin or phosphor copper.

Testing Materials.—The equipment of the new Bureau of Testing Materials of the Prussian Government which is associated with the Technische Hochschule, of Berlin, is described in *Metallurgie*, August 8. The departments for metallurgy and metallography are described in some detail. The room for heating and melting materials contains various electric furnaces which are partly of the simplest kind, made by winding nickel wire around a porcelain tube, and wrapping the whole into an insulating mass; in other furnaces the Joulean heat is produced in strips of very thin platinum foil, made by Heraeus. For rough regulation, a rheostat in series with the furnace is used, while more delicate regulation is accomplished by an adjustable resistance in shunt with the heating wire. By this means it is possible to maintain the temperature in the furnace constant within ± 3° C. and to adjust the speed of heating and cooling. For more exact work, the current is furnished from a storage battery, otherwise from the supply mains.

Copper-Zinc Alloys.—A long paper, by E. S. Shepherd, is published in the *Jour. of Phys. Chem.*, June. Copper and zinc unite to form six series of solid solutions; the author has determined the limiting concentrations of these solid solutions and gives the equilibrium diagram for the system. There are no "definite compounds" between copper and zinc. The author gives an explanation of the red color of brasses low in copper. Forty-four excellent microphotographs of the complete series are reproduced, showing the effect of heat treatment in brass.

Nickel.—A brief illustrated description of the Evje Nickel Works in Norway is given in *Metallurgie*, June 22. The monthly output is 300 tons of ore, giving about 8 tons of nickel and 3 tons of copper.

Correspondence.

LEAD PEROXIDE ANODES FOR THE CYANIDE PROCESS.

To the Editor of Electrochemical Industry:

Sir:—In my paper on "A Development in Electrolytic Precipitation of Gold and Silver from Cyanide Solutions," which you printed in your issue of April, 1904, there is one statement which I should like to supplement. On page 132 I said: "Anodes peroxidized in this way have been in use for the last ten or twelve months, and at the present time have as good a surface as on the day they were first placed in the box."

I am informed from Minas Prietas that eight or nine months after this statement was made, the anodes in question began to

show signs of wasting, and our experience is that when once the surface begins to disintegrate, deterioration is comparatively rapid.

Thus we cannot yet consider these anodes to be permanent, though they are undoubtedly the most satisfactory we have tried. E. M. Hamilton.

Plympton S. Mary, S. Devon.

Book Reviews.

Alternating Currents, Their Generation, Distribution and Utilization. By George T. Hanchett. New York: John Wiley & Sons. 175 pages, illustrated. Price $1.00.

For electric furnace processes alternating currents are in extended use and the manager of an electric furnace plant, while primarily an electrochemist or electrometallurgist, is often confronted with problems of alternating current engineering. The theory of alternating current phenomena and appartus has been splendidly worked out during the past twenty years or so, but most text books and original papers on the subject are of a highly mathematical character, and do therefore not appeal strongly to chemists.

The small book of Mr. Hanchett has been written with an endeavor to explain as clearly and simply as possible, the phenomena as well as the apparatus of alternating currents of electricity in their various practical phases. The author seems to have prepared the book primarily for the use of managers of central stations and constructing electrical engineers, but we think that in view of its plain and clear language the book should be found useful by electrochemists who want to become acquainted with alternating current engineering. The author first gives hydraulic analogies of inductance and capacity combinations and then explains the fundamental principles of alternating-current phenomena. He then deals with the single-phase constant potential transformer, discusses phase difference and vector summation, gives the calculations of copper for polyphase currents and describes the methods of alternating-current measurements. The concluding six chapters of the book deal with the induction motor, the rotary converter, alternating-current generators and synchronous motors and the management of alternating-current machinery and induction motors.

The Alternating-Current Transformer. By F. G. Baum. New York: McGraw Publishing Co. 195 pages and 122 illustrations. Price $1.50.

Although of small size it is one of the most complete and exhaustive treatises on the alternating-current transformer, and the reader who carefully studies the book should gain a good working knowledge of alternating-current phenomena which should enable him to study other problems of alternating-current engineering outside of transformer practice.

The book originated from a course of lectures held at Stanford Uniersity, Cal., and some knowledge of elementary alternating-current phenomena, and of the principles of calculus is presupposed. The ten chapters of the book deal with elementary principles, the simple transformer diagram, graphical representation of pressure relations, regulation, efficiency, testing, systematic design, circuit regulators, constant current transformers, series transformers, compensating voltmeter, connections of transformers for single-phase and polyphase circuits, commercial types of transformers of American and European manufacturers. Extracts from the rules and requirements of the National Board of Fire Underwriters are printed as an appendix.

The reviewer quite agrees with the statement of the author that the student who grasps the theory of the transformer has little difficulty with the more complicated reactions in the induction motor and in synchronous apparatus.

INTERNATIONAL ELECTRICAL CONGRESS.

The International Electrical Congress will convene at the Music Hall of the Coliseum, St. Louis, on Monday, September 12, 1904, 9:30 a. m. The Music Hall is situated at Olive and Thirteenth Streets, in the city district of St. Louis. It is intended that after the opening ceremonies, the convention will immediately divide into sections, the section halls being on the second floor of the same building. The Bureau of Information and the offices of the secretary and treasurer will also be in the Coliseum Building. On Tuesday, Thursday and Friday, the Sections will meet on the second floor of the Coliseum from 9 a. m. to 1 p. m. There will be probably more than 2000 members of the Congress, of which about 75 per cent are from North America and 25 per cent from other countries.

We have already printed lists of paper to be presented in Section A, B and C on page 214 of our June issue, those of Sections D and E on page 258 of our July issue. We herewith give again a revised programme of the electrochemical section.

Section C—Electrochemistry.

Chairman of this section is Prof. Henry S. Carhart, secretary Mr. Carl Hering. The following papers will be presented:

S. Arrhenius, Methods of Determining the Degree of Dissociation.

Dr. W. Borchers, Electrometallurgy of Nickel.

Sherard Cowper-Coles, Electrolytic Methods for the Rapid Production of Copper Sheets and Tubes.

F. Dolezalek (Subject to be announced).

J. Sigfrid Edström, Electrical Extraction of Nitrogen from the Air.

Hans Goldschmidt, Alumino-Thermics.

F. Haber, Electrolytic Disturbances in the Earth.

P. L. T. Héroult, Electrometallurgy of Iron and Steel.

Richard Lorenz, Electrolysis of Fused Salts.

W. Ostwald, Electrolysis and Catalysis.

J. Swinburne, Electrolytic Smelting of Sulphide Ores.

W. D. Bancroft, The Chemistry of Electroplating. (American Electrochemical Society paper.)

A. G. Betts and Edward F. Kern, The Lead Voltameter.

H. S. Carhart and C. A. Hulett, The Preparation of Materials for Standard Cells and their Construction. (American Electrochemical Society paper.)

Thomas A. Edison, The Present Status of Alkaline Storage Batteries. (By Deputy.)

K. E. Guthe, The Silver Voltameter.

L. Kahlenberg, The Electrochemical Series of the Metals. (American Electrochemical Society paper.)

J. W. Richards, The Energy Absorbed in Electrolysis.

T. W. Richards, The Relation of the Theory of Compessible Atoms to Electrochemistry.

The *American Electrochemical Society* will hold an independent session on September 16, which will be a joint session with the Bunsen Society, and the Faraday Society, and to which the members of the Congress will also be invited.

Section A—General Theory.

Chairman of this section is Prof. E. L. Nichols, secretary, Prof. H. T. Barnes. The revised list of papers is as follows:

Moise Ascoli, Systems of Electric Units.

Paul Drude, Metallic Conduction from the Standpoint of the Electronic Theory.

W. Jaeger, Electrical Standards.

H. Nagaoka, Magneto-Striction.

J. S. Townsend, The Theory of Ionization by Collision.

J. J. Thomson, The Corpuscular Theory.

M. J. Violle, Secondary Standards of Light.

C. T. R. Wilson, Condensation Nuclei.

P. Zeeman, Recent Progress in Magneto-Optics.

Howard T. Barnes, The Mechanical Equivalent of Heat Measured by Electrical Means.

Carl Barus, Atmospheric Nuclei.

L. A. Bauer, The State of Our Knowledge Regarding the Earth's Magnetism and Recent Remarkable Magnetic Storms.

D. B. Brace, Magneto-Optics.

H. S. Carhart and G. W. Patterson, Jr., The Absolute Value of the Electromotive Force of the Clark and Weston Cells.

C. D. Child, The Electric Arc.

K. E. Guthe, Coherer Action.

A. E. Kennelly, The Alternating Current Theory of Transmission-Speed over Submarine Telegraph Cables.

E. Percival Lewis, The Electrical Conductivity of Gases.

J. C. McLennan, Radio-activity of Mineral Oils and Natural Gases.

Lewis T. More, Electrostriction.

E. F. Nichols, The Unobtained Wave-Lengths between the Longest Thermal and the Shortest Electric Waves yet Measured.

E. L. Nichols, Standards of Light.

H. Pender, The Magnetic Effect of Moving Charges.

M. I. Pupin, Electrical Impulses and Multiple Oscillators.

E. B. Rosa and F. W. Grover, The Absolute Measurement of Capacity and Inductance.

E. Rutherford, Radioactive Change.

J. Trowbridge, Spectra of Gases of High Temperatures.

A. G. Webster, Report on Recent Developments in Electrical Theory.

Frank A. Wolff, The So-called International Electric Units.

J. Zeleny, The Discharge from Points.

Other Sections.

From the programme of sections B, D, E, F, G, H we give those papers which should be specially interesting to our readers:

Section B—M. A. Nodon, Electrolytic Rectifiers.

Section D—H. W. Buck, Use of Aluminium as an Electrical Conductor.

Section E—A. Wright, Recent Improvements in Electrolytic Meters.

Section E—G. Goettling, Storage Batteries.

Section E—H. N. Potter, Nernst Lamps.

Section E—C. P. Steinmetz, Luminous Electric Arcs.

Section F—J. B. Entz, The Storage Battery in Electric Railway Service.

Section G—G. F. Sever, Electrolysis of Underground Conductors.

Section H—S. Schatzky, The Ionic Theory as Biological Basis for the Therapeutic Action of Electricity.

Section H.—Margaret A. Cleaves, The Nature of the Changes Established in Living Tissue by the Action of Oxidizable Metals at the Anode.

Section H—J. W. Langley, Electric Purification of Water for Drinking.

Section H—Jacques Loeb, Control of Life Phenomena by Electrolytes.

The Government of the United States, at the petition of the Committee of Organization, has issued invitations to the various foreign governments to send official representatives to the Chamber of Delegates of the Congress. Up to the present time the following appointments have been announced:

Austro-Hungary—Prof. Charles Zipernovzky.

Italy, Prof. Moise Ascoli, Prof. L. Lombardi, Ing. A. Maffezzini.

Switzerland, Prof. Ferdinand Weber, Prof. Francois Louis Schüle.

Norway and Sweden, Prof. Svante August Arrhenius.

Australian Colonies, John Hesketh, Esq.

Brazil, Señor Jorge Newbery.

India, J. C. Shields, Esq.

Mexico, Señor Rafael R. Arizpe.

United States, Prof. H. S. Carhart, Dr. A. E. Kennelly, Prof. H. J. Ryan, Prof. S. W. Stratton, Prof. Elihu Thomson.

ST. LOUIS EXPOSITION.

International Acheson Graphite Co.

The exhibit of the International Acheson Graphite Co. is located in section 1, head of aisle "S", in the Electricity Building, and consists of specimens and samples of the two distinct branches of the business of this company, viz., the electrodes and the bulk graphite. These specimens illustrate not only the products as manufactured by them, but also show the various lines of work in which Acheson graphite is proving successful as compared with the natural graphites.

There are also shown four miniature electric furnaces, which are exact duplicates of those used at Niagara Falls, and illustrate various stages in the process of manufacture. One of these furnaces, by the use of gas, illustrates a furnace in actual operation, the gas burning and playing over the surface of the mixture and walls in the same manner as in the larger furnaces at Niagara Falls. Another shows part of the mixture covering removed, exposing the red-hot core. Still another shows the graphite ready to be unloaded and the fourth the method of loading the electrodes into the furnaces for graphitization.

EXHIBIT OF INTERNATIONAL ACHESON GRAPHITE COMPANY.

With respect to the specimens of electrodes, we may refer to their full description in an article by Mr. C. L. Collins, 2nd, published on page 277 of our July issue. In connection with the bulk graphite exhibits, the company illustrates the use of Acheson graphite in the manufacture of paint, stove polish, dry batteries, motor brushes, etc. A special feature is made of the use of Acheson graphite in high-grade protective coatings for structural iron and steel. For this purpose it is stated to be ideal, and is gradually becoming the standard graphite pigment in this country. In some recent tests made by the National Tube Works of McKeesport, an Acheson graphite paint was awarded the highest merit, and is to be used exclusively upon their new plant, covering some eighty acres of ground; these tests extended over a period of eighteen months, and included eighty-three different varieties of protective coatings.

Carborundum Co.

The very attractive and conspicuous exhibit of the Carborundum Co. is on block 16 of Machinery Hall, near the eastern entrance to the building. Raw carborundum, as it comes from the electric furnace (see full description in Electrochemical Industry, vol. I., page 50, 1902), in beautiful crystals, is exhibited in form of a revolving huge pyramid ten feet in height by five feet in diameter at the base. This column of crude carborundum is placed in a most artistic circular pavilion. Around it, the specimens of work done with carborundum are exhibited in showcases. Many exhibits deal, of course, with the various applications of car-

borundum for grinding purposes. A model of Mr. Acheson's electric furnace for making carborundum is exhibited in the Mines and Metallurgy Building. Another special feature is the exhibit of metallic silicon made by the Carborundum

EXHIBIT OF CARBORUNDUM COMPANY.

Co. by Mr. Tone's electric furnace process; it will undoubtedly interest metallurgists. It contains 97 per cent of metallic silicon.

Electric Storage Battery Co.

The exhibit of the Electric Storage Battery Co., is a model battery plant, constructed on exactly the same lines as one forming part of a power house or sub-station. Above this model plant a large map of the United States is suspended, indicating the locations of each of the 1700 storage battery installations which have been made by this company. Spots of different colors indicate the special purpose for which the batteries are employed. There are also shown complete cells for railway work, such as are installed for the St. Louis Transit Co., and cells for automobile work.

Edison Storage Battery Co.

The Edison Storage Battery Co.'s exhibit occupies space adjoining the main Edison booth, which is divided into three sections; the central one is the headquarters of the American Institute of Electrical Engineers, while on the right and left are the offices of the Association of the Edison Illumination Companies and of the Edison historical exhibit, respectively.

The Edison Storage Battery Co. exhibits three of the latest types of the iron-nickel alkaline battery, with parts cut out from one side so as to show the internal construction. One case shows the different parts of the battery; another case contains a historical collection of cells from the first one made by Mr. Edison and showing one cell of each succeeding type. A 40-cell automobile batery is connected to a charging board to show the conditions under variable rate of charge and discharge and to demonstrate the high charge rates which the battery can stand. The exhibit also contains ten different types of the Edison-Lelande primary battery.

Lanyon Zinc Co.

The exhibit of zinc and zinc products by the Lanyon Zinc Co. is located at Block 42B, Mines and Metallurgy Building, and shows the diversity of uses of that metal, and the ease with which it may be worked into many products, not only in the well-known electrical and household lines, but in the many small parts of modern manufacturing processes as well.

The Lanyon Zinc Co., though manufacturers of spelter, sheet zinc, zinc wire, tubes and band only, have gathered together a large number of the manufactured articles for which they supply the material. A handsome cornice and pediment worked up from sheet zinc is a principal feature of the exhibit and forms a background to the space over sixty feet long. The various panels of this are decorated with views of the company's spelters and mills, and at either end stands a grotesque griffin stamped from sheet, these latter being excellent examples of the use of sheet zinc for statuary.

Upon the two large columns which are located symmetrically near the corners of the exhibit, are displayed handsome stamped zinc lions' heads and ornaments, church organ pipes of zinc, a large washboard showing the various styles of ribbing used in standard makes, a section of a flight of stairs, showing in a graphical manner the use of zinc stair treads, nosings and stair corners, white bronze medallions, as well as the name and location of the company arranged in stamped zinc letters brightly burnished. Piles of spelter, a number of casks of sheet zinc, a box of flat sheets, and a table of corrugated zinc, with a large display of wire rods, tubes and bands on reels and in the several show-cases, display the direct products of the Lanyon Zinc Co. Besides these are shown battery parts, organ pipes, zinc nails for roofing purposes, zinc roofing tile, corrosion-preventing plates for marine and stationary boiler use, zinc cable hangers, cyanide discs, fruit jar tops and bottle top specialties, dry battery cups, etc. Galvanized sheets and various articles should not be omitted from mention, as 50 per cent of the spelter produced in this country is consumed for galvanizing purposes.

EXHIBIT OF LANYON ZINC COMPANY.

The brass trade is represented by the brass posts of the railing surrounding the exhibit, the horizontal rails of which are composed of pure zinc tubing, making a pleasing combination of colors. In fact, the ever-widening avenues of zinc consumption are excellently represented.

In addition to this main exhibit the company is also represented in the Metal Pavillion at the end of the Mining Gulch, which building they roofed with zinc, for which purpose zinc seems specially adapted, on account of its remarkable durability. This building is also lined with corrugated sheet zinc which is coming more and more into favor for factory buildings, train sheds, warehouses and the like.

Goldschmidt Thermit Co.

The exhibit of the Goldschmidt Thermit Co. is located in the Metals Pavilion, a building opposite the south corner of the Mines and Metallurgy Building. The exhibit covers the whole of the aluminothermic process. The ignition of an appropriate mixture of metallic oxides and finely-divided aluminium results in the almost instantaneous reduction of the oxides to pure metals, with the development of an enormous amount of heat, so that temperatures estimated at about 5400° F. are easily produced without any supply of heat or power from outside. Concerning further details, the reader may be referred to the extensive descriptions of the applications of the process by Dr. Hans Goldschmidt in our issues of November, 1903, p. 527, and April, 1904, p. 145.

The exhibits of the Goldschmidt Thermit Co. may be roughly divided into two classes. The first is the display of pure metals, such as chromium, manganese, molybdenum, ferro-vanadium and others (free from carbon, because produced by reduction with aluminium). The second class of exhibits shows the application of thermit to welding iron and steel. The appliances used, consisting of crucibles and moulds, are shown in position, and a number of welded objects, such as girder rails, shafts, pipes, etc., demonstrate the efficiency and usefulness of the process. The process is also shown in actual use, and thoroughly explained by demonstration daily at 4 o'clock in front of the exhibition space. Mr. W. M. Carr is in charge of the exhibits.

The Roessler & Hasslacher Chemical Co.

Among the exhibits of American manufacturers in the chemical industries, that of The Roessler & Hasslacher Chemical Co. in the Palace of Liberal Arts deserves more than a passing notice, being most artistically designed and executed. This firm has conceived and carried out the unique idea to use the picture of an alchemist as the background for their exhibit, and thereby make the same interesting for every visitor, even if not concerned in the chemical line.

Their booth, 20 feet long, 20 feet wide, and 18 feet high, represents a building of massive stone construction of the Middle Ages, with a view through the large archway disclosing the interior of the alchemist's study and workshop, while in two windows on the side aisle a special feature is made of the ceramic colors and peroxide of sodium which they make, by showing actual specimens of work done with these two articles. The Old Alchemist scene is a reproduction from the well-known painting of the famous old master, D. Teniers, Jr., now at the Museum in Brunswick, Germany.

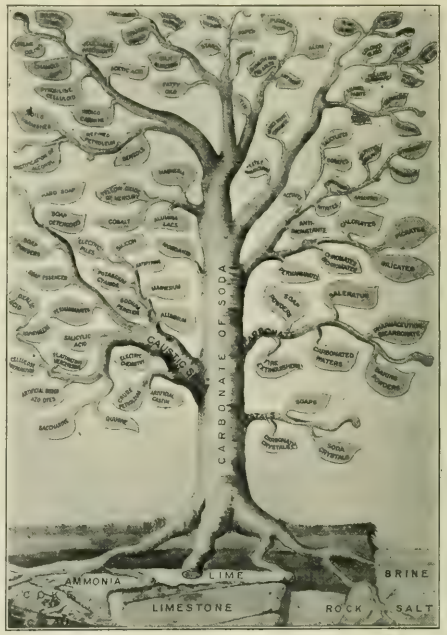
The Roessler & Hasslacher Chemical Co., who in 1884 started their works at Perth Amboy, N. J., to which they have since added materially, and also have an electrolytic plant at Niagara Falls, known as the Niagara-Electro-Chemical Co. (see Electrochemical Industry, vol. I., p. 14, 1902), have been the pioneer makers of a certain line of chemicals, among which are the following on exhibition. Acetone, which is a good solvent for fats, resins and camphors, and is used in the preparation of smokeless powder; chloroform; formaldehyde, a disinfectant, insecticide, preservative, which is coming into general use; metallic sodium, which is used in the laboratory and mining, and from which sodium cyanide is manufactured. The Roessler & Hasslacher Chemical Co., being the first in 1890 to start the manufacture of cyanide of potassium of 98 to 99 per cent purity, now produce a high grade cyanide of sodium, equivalent to 128 to 130 per cent cyanide of potassium. The cyanides are extensively used in electroplating and for the extraction of gold and silver from ores, tailings, etc.

In the ceramic window all shades of their enamel and underglaze colors, fluxes and metallic oxides for decorating in the china, clay and glass industries are shown, as also liquid bright gold; platinum and silver preparations which at once give after burning, without burnishing, a bright gold, platinum or silver surface.

The peroxide window is occupied entirely by the products of the textile mills, substituting the modern peroxide of sodium bleaching methods for the old and injurious process and method of bleaching with lime and sulphur. Recently the firm has also taken up the sale of metals, such as metallic chromium, magnesium, molybdenum and tungsten, and of the ferro-alloys of these metals which are coming into very extended use in making special steels, as is also high-grade ferro-silicon, 25 to 50 and 75 per cent, replacing the furnace-made products.

Mallinckrodt Chemical Works.

The exhibit of the Mallinckrodt Chemical Works, of St. Louis, is located in the southeast corner of the Palace of Liberal Arts, opposite the Government Building, in the section devoted to chemical, pharmaceutical and surgical instrument displays. The exhibit illustrates the advance made by this firm in the manufacture of pure chemicals for medicinal, photographic and other purposes. The main portion of the exhibit is installed in a massive mahogany case, 18 feet long, by 12 feet wide, completely enclosed with plate glass, which permits of an unobstructed view of the pretty effect produced by the multitude of specimens of chemicals put up in handsome cut-glass bottles, mushroom glasses, etc., many of which were especially made and imported for this display. The side of the case facing aisle G is, perhaps, the most attractive portion of the exhibit on account of the background being arranged with large plate-glass mirrors. In this division of the case are



TREE REPRESENTING THE MANUFACTURE AND THE USES OF CARBONATE OF SODA (SOLVAY PROCESS CO.)

placed the gold, silver and platinum salts, cocaine, caffeine, and a number of the rarer and more expensive alkaloids.

Among the numerous substances on exhibition are morphine, codeine, cocaine, strychnine, caffeine, carbolic acid, bismuth preparations, calcium salts, anaesthetics, mercurials, hydro-

EXHIBIT OF SOLVAY PROCESS COMPANY.

gen peroxide, iron preparations, pure granulated salts, salts of lithium, potassium, sodium, aluminium, etc. There is also a full exhibit of all kinds of chemicals used in photography.

Solvay Process Co.

The exhibit of the Solvay Process Company, of Syracuse, N. Y., consists of good-sized samples of their various products, which are carbonate of soda, bicarbonate of soda, caustic soda, calcium chloride crown filler, and samples of raw materials from which soda products are made. The adjoining diagram shows a tree illustrating the method of manufacture of carbonate of soda and the great many compounds of organic and inorganic chemistry which are made from it. The exhibit is located in the New York section of the Department of Mining and Metallurgy. Above the samples of their products, various pictures are exhibited showing what the company has done to elevate the social condition of their workmen. These pictures represent the "Guild Hall," "Hospital," Dining-Room," etc.

American Hard Rubber Co.

The American Hard Rubber Co., of New York, has a very fine exhibit in the Palace of Liberal Arts at the intersection of aisles 7 and H, block 65. This company is showing acid pumps, piping, fittings, dippers, battery jars, etc., all made of hard rubber and designed especially for the conveyance of acids, chemicals and alkaline solutions.

This exhibit should be of particular interest to chemical manufacturers, electrochemists, chemical engineers and all connected with chemical and electrochemical industries, on account of the well-known fact that hard rubber is impervious to the action of acids, etc., and practically non-corrosive.

Allis-Chalmers & Bullock Electric Manufacturing Co.

These companies exhibit the largest generating set at the World's Fair. It is centrally located in the middle bay of the Palace of Machinery, and consists of the 5000-hp. Allis-Chalmers engine, and the Bullock alternator. It was installed, not only as an exhibit, but plays an important part in supplying power for the decorative lighting on the exposition grounds, and for other purposes. In the evening the set supplies current for nearly 200,000 incandescent lamps of 8 c. p.

The 3500-kw. Bullock generator which, like the engine, is capable of carrying a steady overload of 50 per cent, gives three-phase 25-cycle currents at 6600 volts, running at 75 r. p. m. This generator has attained a regulation within 6 per cent, while the engine can be regulated within 2 per cent.

Leeds & Northrup Co.

The Leeds & Northrup Co., of Philadelphia, have all of their apparatus and instruments exhibited as part of the exhibit of the National Bureau of Standards in the Electricity Building.

The National Bureau of Standards is making an extensive working exhibit, which, to a considerable extent duplicates their equipment at Washington, and it will maintain a large working staff at St. Louis. By arrangement with the authorities of the Exposition, it is to act in an official capacity in calibrating and standardizing instruments for the Jury of Awards, and in making tests for them. In order to have the necessary apparatus to make this working exhibit without depleting the equipment of the Bureau at Washington, various manufacturers have furnished apparatus and instruments for the exhibit of the bureau. Among them are the Leeds &

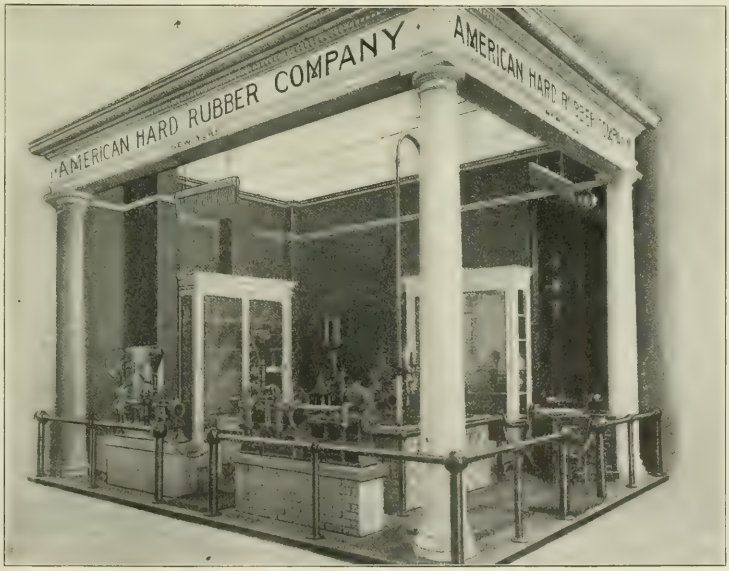


EXHIBIT OF AMERICAN HARD RUBBER COMPANY.

Northrup Co. Among the apparatus exhibited by this company are resistance boxes and Wheatstone bridges, Carey Foster bridges, resistance standards, apparatus for measuring low resistances, potentiometers, d'Arsonval galvanometer, keys, condensers, self-induction apparatus, curve tracers, etc.

Of special interest should be the form of Kohlrausch slide

wire bridge, which was designed by the Leeds & Northrup Co., with the intention to have all the advantages of the original form of Kohlrausch bridge without its disadvantages. The latter are uncertain contact resistances in the bridge circuit, due to the brushes through which the current passes to the wire, and uncertain contact in the galvanometer circuit made by poor contact of the roller on the wire or of the roller on the rod on which it moved. To accomplish this, the contact is made movable and the polished cylindrical stone on which the wire is fastened is fixed. In this way both ends of the wire have reliable soldered connections out to the binding posts, and the connections in the contact circuit are also soldered, except that found between the long nut moving on a large screw which moves the contact arm up and down as it rotates. This, on account of its ample size, is entirely reliable. The wire makes ten turns around the stone cylinder and the total resistance is about 5 ohms. A vertical scale shows the number of turns, and the fraction of a turn is read from a circular scale, which is divided to 200 parts and can easily be estimated to tenths of a division. The advantage of the rubbing contact over the rolling contact of the original form is stated to be very marked, and to be entirely reliable.

Another very convenient and very carefully designed instrumnt exhibited by this company is their standard potentiometer.

Missouri Electric Water Purifier Co.

This company exhibits in the court of the Electricity Building the Kune process of purifying water, the electrolytic action of the anode producing an insoluble hydrate which coagulates the impurities in an insoluble mass, so that when the water has passed through a filter the impurities remain back. The purifier has a capacity of 500 gallons of purified water per day, the current consumption being 30 amperes at 15 volts.

Buffalo Forge Company.

As the Buffalo Forge Co., the Buffalo Steam Pump Co., and the George L. Squier Manufacturing Co. are under one management, their various products are exhibited collectively. Their booth is located in the Palace of Machinery, Group 62, Block 27, Aisle G. Due to the limited space, only a few of a complete line of engines for electric lighting and general power purposes are exhibited. Near the front of the display, in connection with the forge shop equipment, are blowing and exhaust fans direct-connected to electric drives. Fans are also shown that may be used for exhausting chemical fumes. Such fans have an interior construction that resists the action of the gases handled. (See Electrochemical Industry, August, 1904, p. 332.) One of the simpler types of the Buffalo Forge centrifugal pumps is included in the exhibit. These pumps can be built of hard lead, brass, etc., for use in chemical works, the material being such that it will not be affected by the liquid pumped.

There is also a large line of direct-acting steam pumps for water works, mine and other service, including jet condensers and air pumps. A fire underwriter pump of the very latest approved design forms a part of this company's display.

Those interested in the chemics of the manufacture of sugar will have an opportunity of seeing a complete line of machinery as manufactured by the George L. Squier Co. Their part of the exhibit also includes coffee-drying and rice machinery.

In addition to the regular exhibit, the Buffalo Forge Co. have installed extensive mechanical draft apparatus in the Steam, Gas and Fuels Building. The Heine, Cahall, Belleville & Niclausse boilers are using their equipment. The short stacks of the power plant here are in direct contrast to those at the Paris Exposition, where natural draft was depended upon. The many unique features of this apparatus will be extremely interesting to those not in touch with the latest developments along this line.

R. D. Wood & Co.

Messrs. R. D. Wood & Co., of Philadelphia, have exhibits at two different places of the Exposition. The first is found in the Steam, Gas and Fuel Building, or Power House, adjoining Machinery Hall. It includes a live or working exhibit of a 350-hp. producer gas-power plant on their well-known pressure system, and also a 25-hp. suction gas-power plant operating a 22-hp. gas engine (Nash engine).

The pressure plant furnishes producer gas to a number of gas engines in National Meter Co's. exhibit in Machinery Hall through a pipe line. This plant comprises one of the R. D. Wood & Co's. revolving ash table gas producers, equipped also with the Bildt continuous automatic feed, and, in the order of their connection from the producer, an economizer, scrubber, tar extractor, purifier and gas holder. As thus arranged the plant may operate on soft or hard coal.

In this R. D. Wood & Co. system arrangement is made through the economizer to return to the producer in the steam and air blast what would otherwise in cooling be a loss of heat by the sensible heat of the gas.

Another interesting feature is the attention paid to the minimizing of labor. The coal is received from the railroad car in a conveyor hopper, which conveyor carries it to the elevator boot from which the bucket elevator raises and discharges it into an overhead coal bin. By suitably arranged gates the attendant charges the storage magazine from this coal bin of the Bildt feed. The latter then continuously and uniformly feeds the coal to the producer. The coal handling is thus made, as far as practicable, automatic.

The suction producer plant presents a neat and compact appearance, having its gas generator and evaporation in one element. Then follows in order the scrubber and receiving tank, from which the engine draws its supply. As is understood, the forward stroke of the engine piston in this design of plant draws the requisite air through the fuel bed and the generated gas to the engine. The engine is used, as thus driven, in operating the coal elevator and Bildt automatic feed.

2333-KW TRANSFORMER. GENERAL ELECTRIC COMPANY.

These present a very interesting exhibit to those concerned in fuel economy in power generation, a horse-power per hour being secured with good gas engines on from a pound to 1¼ pounds of coal.

An 84-inch diameter pipe, bell and spigot, reminds the visitor that it comes from R. D. Wood & Co., Philadelphia, who, by the way, are the oldest manufacturers of such pipe in

the States. As it forms the vestibule, so to speak, of their exhibit space, many pass through it daily and many are the guesses as to its diameter.

A sectional cut through a cast-iron side-suction centrifugal pump gives a good idea of their construction and finish, which attracts much attention.

There are also exhibits of the R. D. Wood & Co. high-pressure hydraulic valves as used in the control of the hydraulic appliances made by the firm and extensively used in iron and steel industries where durability and nicety of adjustment with minimum repairs are important factors.

Messrs. R. D. Wood & Co. have also an exhibit at the United States Geological Survey's Coal Testing Plant in the "Gulch." This installation will be used in testing a great variety of soft coals bought by the Government for this purpose. It is essentially of the same construction as the plant above described, except in its coal handling. It will furnish gas to a 260-hp. Westinghouse gas engine.

Otto Gas Engine Works.

The exhibit of the Otto Gas Engine Works, of Philadelphia, is located at space 41 of Machinery Hall, main aisles D and E, cross aisles 7 and 8. They are exhibiting 17 engines, consisting of all purpose engines, marine engines, farm or portable engines, hoisting engines, and engines specially built for electric light work. Eleven of these are piped up and running.

An installation which proves of special interest, is a 40-hp. single cylinder, " hit and miss" governed gas engine, directly connected to a 30-kw. generator. It furnishes current to several 110-volt enclosed arcs, and the main points of interest is the close regulation obtained, there being less than 3 volts variation under varying loads and extremely steady lights under partial load, as low as one-third. There is also on exhibition a 10-hp. gas engine, single cylinder, hit and miss

MODEL OF 10,000-HP VERTICAL SHAFT GENERATOR. GENERAL ELECTRIC COMPANY.

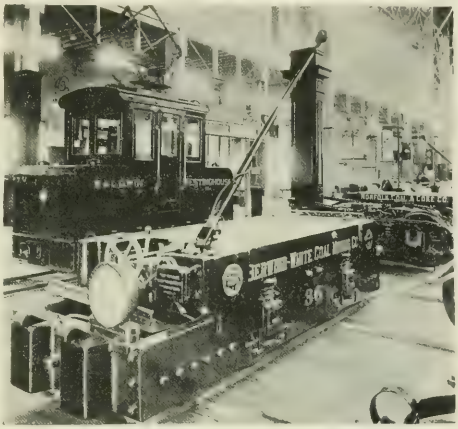
type, belted to a 6-kw. generator, which furnishes power to incandescent lights and fans.

These engines are of great interest for small isolated plants, since almost any form of gaseous or volatile fuels can be used. The space of the exhibit is lighted and cooled by power furnished by the gas engines.

Stilwell-Bierce & Smith-Vaile Co.

The Stilwell-Bierce & Smith-Vaile Co., of Dayton, Ohio, have the following apparatus on exhibition:

One 7000 square foot surface condenser, steel shell type, which is to be operated in connection with 1000-kw. steam turbine manufactured by Hooven, Owens & Rentschler, of Hamilton, Ohio; the maximum output of the turbine, with 50 per cent overload, is 33,000 pounds of steam per hour; the condenser must create, therefore, and maintain a vacuum of from 27 to 28 inches, based upon a 30-inch barometer, with a



BALDWIN-WESTINGHOUSE ELECTRIC LOCOMOTIVES.

temperature of refrigerating water not to exceed 80° F. A jumping engine and two vacuum pumps belong to this plant.

The company has also furnished for a vertical cross-compound Hamilton-Corliss engine, one 4000 square foot surface condenser of the rectangular and shell type, for condensing approximately 35,000 to 40,000 pounds of steam per hour maximum, and maintaining a vacuum of 26 inches and above, based upon a 30-inch barometer. The circulating pump is of the compound, direct-acting type, duplex pattern; the vacuum pump is of the combined wet and dry type.

The machinery is located within the confines of Machinery Hall, at the west end of block 45, immediately west of the north entrance of Machinery Hall. For the boiler plant various pumps were installed by the company, while they have on exhibition in the Mining Industries Building a special feed-water heater for a pump to be used in connection with gold-cleaning apparatus.

General Electric Co.

The exhibit of the General Electric Co. in the Electricity Building consists of very carefully selected examples of its latest and most representative work. A striking instance is the full-sized model of the 10,000-hp. vertical shaft generator for the Canadian power plant at Niagara Falls. Five of these machines are being installed, these being the largest dynamos ever constructed. The model represents the stationary armature of the machines resting on a concrete base.

Among the railroad exhibits is a 7-ton mining locomotive equipped with a cable reel which automatically winds as the locomotive advances or backs up. This new cable relay is a feature highly appreciated by mining engineers, since it allows electric locomotives to be run into new portions of the mine where trolley wires have not yet been installed; at the same time there is no danger of the cable becoming tangled up or run over by the locomotive, which frequently happens when the winding of the cable is left to the man operating the loco-

motive. The cable drum contains 700 feet of cable, and the locomotive automatically winds this up. The cable drum is geared to the locomotive axle through the medium of a friction clutch, which allows a certain amount of slip, but does not let the cable get entirely slack.

Among a great number of small motor applications are a 24-inch electrically operated Chapman valve, a centrifugal sugar-drying outfit with direct-connected vertical shaft motor, electric buffing and grinding machines, etc.

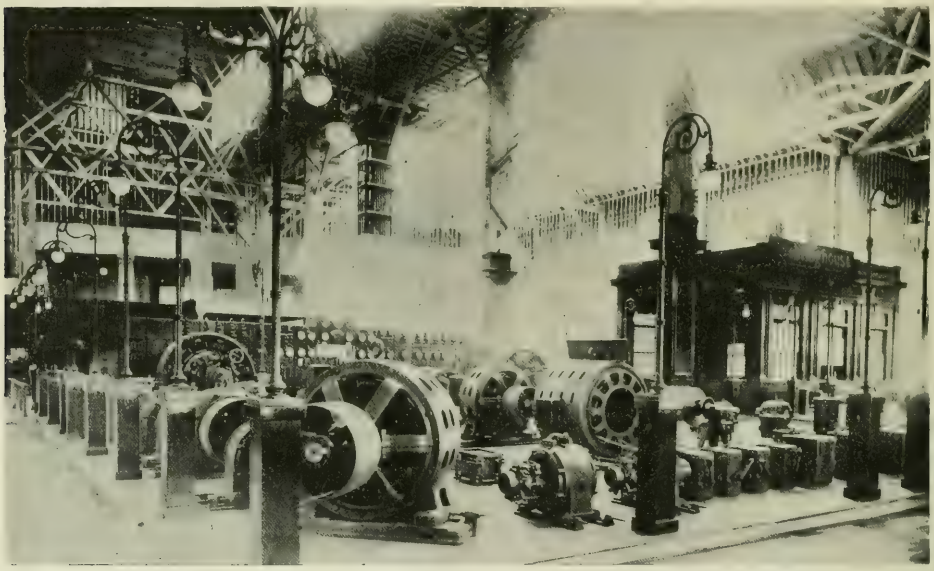
A special feature of the exhibit is the Steinmetz mercury vapor arc lamps which are here exhibited for the first time. There is also a mercury vapor rectifier with a capacity of 10 amperes direct current, shown side by side with a motor generator set for doing the same work, the cost of which, however, is double that of the mercury vapor rectifier.

The Westinghouse Companies.

The various organizations associated with the name of George Westinghouse have united in representation at St. Louis under the title of the "Westinghouse Companies at the Louisiana Purchase Exposition." The exhibits of these companies occupy a total of 65,620 square feet floor space. The main service plant of the exposition, for which the Westinghouse Electric and Manufacturing Co. received the general contract, comprises four big electric generating sets, each of 2,000-kw. capacity, located in the center aisle of Machinery Hall. In this hall, in addition to the generating plant and the main exhibit of the Westinghouse gas engines, turbo-generators, rotaries, exciters and motors in operation, is the Westinghouse auditorium with a seating capacity for 350 persons, in which are displayed at regular hours during the day the mutoscope pictures of scenes in and about the various works in Pittsburg. Through the courtesy of the companies this auditorium will be used throughout the fair as a meeting-place for scientific societies and technical congresses. The lighting of the hall is with incandescent lamps of the Sawyer-Man Electric Co., Nernst lamps, Bremer arc lamps, and Cooper-Hewitt mercury vapor lamps, all of which are used extensively throughout the Westinghouse display.

In the Palace of Electricity, the Westinghouse Electrical & Manufacturing Co. occupies the space of over 10,000 square feet, including 1,600 square feet devoted to the display of electric trucks and locomotives, constructed in conjunction with the Baldwin Locomotive Works. Two locomotives built for mine services are shown, one weighing 20,000 and the other 30,000 pounds, each equipped with two No. 75 motors at 500 volts.

An important part of the Westinghouse installation is the pumping apparatus under the beautiful cascades in front of Festival Hall, supplying 90,000 gallons of water per minute for the cascades, by three large centrifugal pumps each driven by a 2,000-hp. Westinghouse induction motor. These are probably the largest motors ever constructed. Of the enormous number of highly interesting exhibits of the various Westinghouse companies, we have been able to mention only these few which should prove of special interest to our readers.



CORNER VIEW OF WESTINGHOUSE ELECTRIC MANUFACTURING COMPANY EXHIBIT.

Crocker-Wheeler Co.

The power plant of the intramural railway, situated in block 42, Machinery Hall, near the main entrance of the building, is the chief exhibit of Crocker-Wheeler Co., of Ampere, N. J. The electric generating equipment consists of seven operating units with a combined capacity of 3500 kw. Six of the generators, with an output of 900, 600, 500, 500, 500 and 400 kw., respectively, are driven by engines of various types, two being of horizontal cross-compound form, two vertical cross-compounds, one horizontal tandem compound, and one a large simple engine.

The last generating unit in the series is of an entirely different type, consisting of a 100-kw. generator, driven at a speed of 700 r. p. m. by a water-wheel operating under a pressure of 300 pounds per square inch at the nozzle. The water-power is supplied by a pump with a capacity of 1200 gallons of water per minute. The water-wheel is furnished by the Abner-Doble Company, of San Francisco, and the pump by the Jeanesville Iron Works Company.

With the exception of differences in size and in details of proportion, the several generators are similar. The machines

are compact, and great care is given to the design of the electrical and magnetic circuits. All parts are constructed with a view toward simplicity, effectiveness and steadiness of operation under continuous heavy loads or rapid load fluctuations. At the close of the Exposition these power units will be available for shipment to any part of the country.

NORTHERN ELECTRICAL MANUFACTURING CO.

The exhibit of the Northern Electrical Manufacturing Co., of Madison, Wis., is located in section 14 of the Palace of Electricity, and is devoted to an illustration of variable speed motor operation of machines and tools.

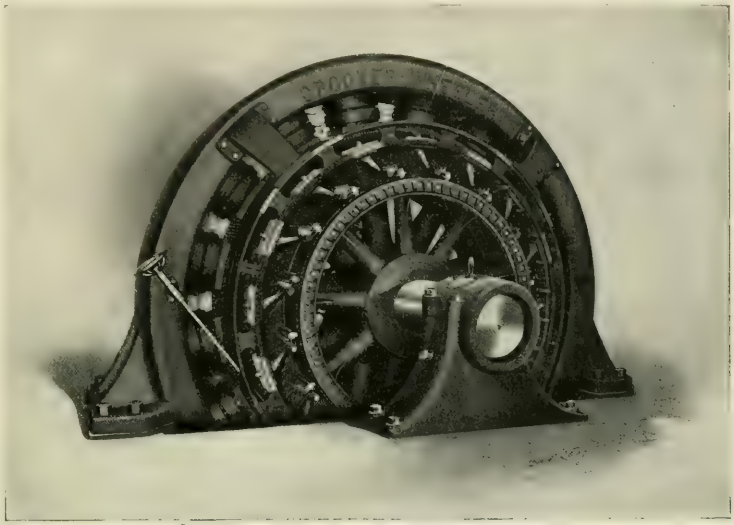
The exhibit includes a full line of Northern direct-current motors from ⅛-hp. to 50-hp., and a 75-kw. generator. Additional to the standard spherical motors shown, are Northern crane motors built in box-type frames, ranging from 1 hp. to 25 hp., and a Northern square elevator motor at 10hp., with a speed variation of 2 to 1.

An item of especial interest to our readers is the 4-hp. Northern dust-proof buffer. This is a self-contained, variable speed equipment, comprising a special Northern dust-proof motor mounted upon a suitable stand in which is contained the motor starter and speed-varying device. The exhibit also includes three Northern dust-proof grinders of the same general characteristics as the buffing lathe with special features adapting them for grinding service.

EXHIBIT OF NORTHERN ELECTRICAL COMPANY.

The machine tools in the exhibit driven by Northern variable speed motors are all in operating condition and afford variations as high as 2 to 1, with current derived directly from the Exposition Company's two-wire single voltage power circuit. The machine tools include various lathes, boring and milling machines, shapers, drills, cutters, etc.

The constant-speed motors in the exhibit operate various fans, drills, grinder, shapers, pumps, etc. Scattered through the grounds in the exhibits of the manufacturers of machinery are located a number of Northern constant-speed and variable-speed motors driving grinders, pipe threading machines, milling machines, engine lathes, cutter grinders, automatic screw machines, turret lathe, vertical boring mill, horizontal boring mill, floor-surfacing machine, corn crusher and grinder, magnetic ore separators, oil compressors, and a rope tramway.



CROCKER-WHEELER 750-KW. GENERATOR.

NATIONAL ELECTRIC CO.

The National Electric Co., successor to the Christensen Engineering Co., Milwaukee, have an extensive exhibit in Section 6 of the Electricity Building. A 400-kw. direct-current engine-type generator is the largest unit shown at this space; a 150-kw., 500-volt, direct-current generator is driven by a 20-hp., 220-volt motor, and in addition to these there is in operation a 150-kw., 3200-volt alternator, a 10-kw. motor generator set, and a 60-kw., 500-volt, direct-current generator belted to a 30-hp., 220-volt motor.

A three-car train shows the operation of their air brake control. Stationary and portable air compressors are also shown.

EXHIBIT OF NATIONAL ELECTRIC COMPANY.

At block 46, of the Machinery Building, may be seen the National 1500-kw., 6600-volt, three-phase, 25-cycle alternator, running at 85 r. p. m. This generator is directly connected to a 2250-hp. engine and furnishes power for the immense

streams of water which flow over the cascades, the largest artificial water falls in the world. This generator is of the revolving field type, and, at unity power factor, it has an efficiency of 95.5, 95.5 and 94.75 per cent at 1¼, full and half load, respectively. For a power factor, equal to unity or zero, the regulation is 5.5 or 22 per cent, respectively.

Electric Controller & Supply Co.

The exhibit of the Electric Controller & Supply Co., of Cleveland, Ohio, is found in section 5, space 28 of the Palace of Electricity. The striking feature is the direct motor drive for planers. This drive brings the planer to the same high efficiency as the motor-driven lathe. The motor is geared direct to the cross-shaft, and instant change and control of speed is obtainable without changing gears or stopping the planer.

A new system of control specially adapted to mill table motors is shown in operation. This controller makes it impossible to injure the motor by "plugging."

Several distinct lines of crane controller are shown. These controllers are specially designed to withstand the rough handling, usually the lot of such apparatus in mills and factories. They are all built with the resistance self-contained. All parts are easy of access for inspection, and wearing parts are made renewable, thus cutting the repair expense to a minimum.

A line of knife switches, cast grid resistance banks, solenoids, magnetic friction and stop brakes and crane fittings are shown, and a working exhibit of the "Clark" lifting magnet. This magnet is suspended on a Brown Hoisting Machinery Co. tramway hoist, and will be of special interest to those who have billets, slabs or plates to handle.

Lidgerwood Manufacturing Co.

The standard hoisting engines and hoisting and conveying apparatus, exhibited by the Lidgerwood Manufacturing Co., of New York City, have been carefully selected so as to avoid the warehouse idea as much as possible. Since this company makes practically every class of engine employing a winding drum, whether operated by steam or electricity, and has built hundreds of varieties of special engines for every conceivable kind of hoisting service (having manufactured up to the present time over 23,000 hoisting engines, boilers and electric hoists), the standard types exhibited represent relatively few styles only, but they are well-selected, so as to give a good idea of workmanship and design. Most of the exhibits of the Lidgerwood Manufacturing Co. are located in sections 30 and 34 of Machinery Hall.

Among the various machines exhibited the following should be of special interest: A ship winch for use on two U. S. battleships, driven by a 40-hp. electric motor; a standard double-drum engine with latest form of apparatus for swinging the boom of an ordinary derrick, while simultaneously the boom is being raised and the load hoisted; a small single-drum engine for miscellaneous hoisting work in docks, warehouses, etc., and also useful for small mining work; an erection and pile-driving engine, combining with the double-friction drums

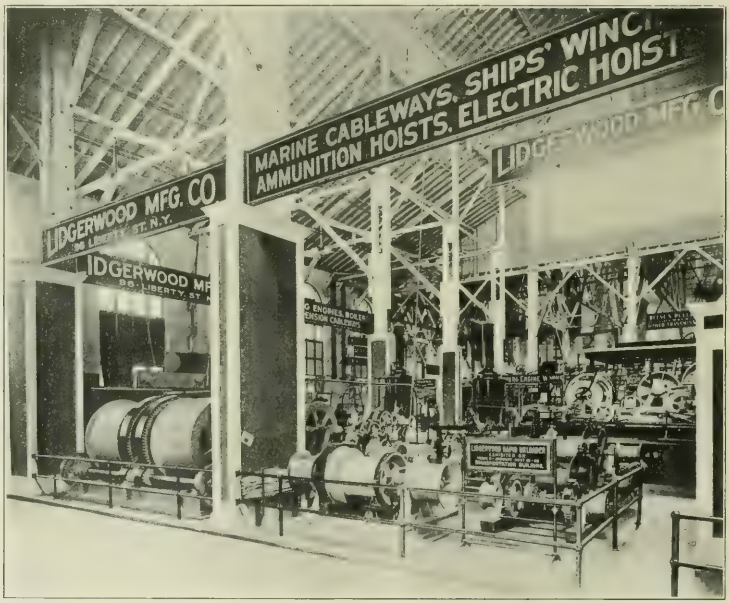


EXHIBIT LIDGERWOOD MANUFACTURING COMPANY.

necessary for pile-driving or derrick work, four independent winch heads for bridge and erection work; a belt-driven hoist, etc.

Among the hoists specially designed for mining, is a standard type of reversible link-motion mine hoist, rated for a load of 3000 pounds to be hoisted at a speed of 350 feet per minute. There is also exhibited an electric mine hoist of a very simple and useful type, since it may be used either as a reversible hoist or as a friction-drum hoist, in the latter case using the power for hoisting and lowering by means of the loose friction drum with the brake. Of great interest is also a double-drum mine hoist; it is an engine designed for either double compartment shafts or for inclines and rail-rope haulage; it is very flexible, for the drums may be thrown into gear, and it may then be used as a regular reversing engine, or the drums may be operated independently by means of the frictions. For tail-rope haulage, one drum winds in the main rope, while the other is loose and pays out the tail-rope under control of the brake.

There are also exhibited models of the Lidgerwood interlocking skidder and of the Lidgerwood traveling cableway, while in the Transportation Building, on track 14, opposite post 65, the Lidgerwood ballast unloader is exhibited, in use for ballast unloading by all the principal railroads of this country and Canada.

Lunkenheimer Co.

In the Machinery Hall, location -5 G-Block 26, is the exhibit of the Lunkenheimer Company; it is easily identified by a large model of their familiar valve in hand, which occupies a prominent corner of their exhibit. Pyramids of globe, angle, cross, lever and gate valves, of various designs and sizes, both brass and iron, are artistically arranged about the exhibit.

The glass cases arranged in front of the exhibit contain a smaller class of the goods manufactured by them, such as lubricators, oil and grease cups, cocks, etc., of all sizes. Neat designs of racks containing various sizes of whistles, injectors, pop valves and a variety of other specialties lend to make up an exhibit worthy of notice. A new design of water gauge, and oil-pump for cylinder lubrication, are features in

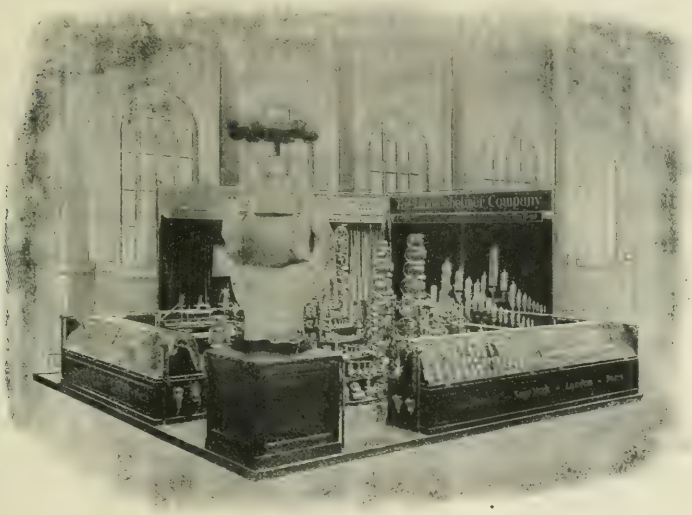


EXHIBIT OF LUNKENHEIMER CO.

themselves. Dispersed about the exhibit are pipe fittings of every description, together with whistles, safety and check valves and numerous other appliances.

Brief Notes.

The Niles-Bement-Pond Co. have a very extensive exhibit of machine tools in sections 17 and 25 of the Palace of Machinery. All machines exhibited are either of entirely new designs or embody radical modifications of older patterns. All the larger machines are driven by direct-connected motors. There is also exhibited a Niles 40-ton electric traveling crane.

The Primos Chemical Co., of Primos, Pa., has an exhibit in block 31 in the Mines Building, in the Department of Mines and Metallurgy. Their exhibit consists in the main of ores of tungsten, and the products made therefrom, such as tungstate of ammonia, tungstate of soda, tungstic acid, ferrotungsten, tungsten metal, etc. The exhibit also contains molybdenum ores and products therefrom, like ferro-molybdenum, molybdenum metal, etc.

The C. O. Bartlett & Snow Co., of Cleveland, Ohio, have an exhibit of one of their style C, No. 3, four-compartment, direct-heat rotary dryers in the Government Testing Plant for determining the value of the different coals, and especially the lignite coal in that building.

The Bausch & Lomb Optical Co., of Rochester, N. Y., have no exhibit of their own, but a great many of their optical instrument and chemical apparatus are exhibited by larger dealers.

Messrs. Eimer & Amend, of New York City, have an exhibit of nickel laboratory ware in connection with the exhibit of the International Nickel Co., and an exhibit of radium, electric furnaces and pyrometers in the Department of Mines and Metallurgy, block 40. Various of the European manufacturers whose specialties this firm deals with are directly represented by exhibits.

The Zucker & Levett & Loeb Co., of New York City, are exhibiting nickel anodes and nickel salts in connection with the exhibit of the International Nickel Co., showing various forms of nickel anodes, flat and corrugated, with and without patent hook.

The Lagonda Manufacturing Co., of Springfield, Ohio, have a very complete display of their cleaners, boiler-room and steam specialties in the Steam, Gas and Fuel Building.

The booth of the Weston Electrical Instrument Co. is one of the most beautiful in the Electricity Building. It contains a very fine display of the Weston standard electrical instruments.

The booth of the National Carbon Co. is made entirely of immense blocks of carbon cut in the form of columns, arches, etc., and set together like large timbers.

The Laboratory & School Supply Co. (the New York branch of the Vereinigte Fabriken f. Laboratoriumsbedarf, of Berlin) have an extensive exhibit of chemical and physical laboratory apparatus and instruments (among them Luepke's apparatus for electrochemical work) in connection with the Educational Laboratory exhibit of the German Government, Department of Education, in the Electricity Building, section 35. They also exhibit a complete equipment of a chemical laboratory for an agricultural experimental station in the Palace of Agriculture, German Division, block 131.

Though the Ward Leonard Electric Co. are not themselves exhibitors, a large number of apparatus of their make are used in the exhibits of other manufacturers, especially motor starters, field rheostats, circuit breakers, etc.

The Willard Storage Battery Co., while having no special exhibit, have installed all of the batteries that are running electric launches there; the service is stated to have been quite successful.

The Denver Fire Clay Co. has an exhibit of their goods at the Metal Pavilion. This company handles a large variety of apparatus, used by chemists, assayers and metallurgists, including muffle furnaces made for both coal and wood. apparatus for use in the extraction of precious metals by the cyanide process, etc.

PERSONAL.

Dr. Willis R. Whitney, professor of theoretical chemistry at the Massachusetts Institute of Technology, has resigned to take full charge of the research laboratories of the General Electric Co.'s works in Schenectady, with which he has already been connected for some time.

Dr. Hans Goldschmidt, the distinguished inventor of aluminothermic methods, sailed from Europe on August 23, by the steamer "Moltke," and will attend the International Electrical Congress at St. Louis as the official delegate of the Bunsen Society. On the request of the authorities of the Congress, Dr. Goldschmidt will deliver a lecture on aluminothermics, with numerous demonstrations at one of the evening sessions. Provisionally, the date has been fixed for September 13, to take place in the hall of the Westinghouse Co.

OBITUARY.

William Weightman, of the firm of Powers & Weightman, the well-known chemical manufacturers of Philadelphia, died at his home on August 25, at the age of ninety-one. Mr. Weightman was born at Grimsby, Lincolnshire, England, on September 30, 1813. In early youth he left England, at the suggestion of his uncle, John Farr, founder of the present firm of Powers & Weightman, and came to Philadelphia, entering the service of his uncle as clerk, which position he occupied until 1836, when John Farr associated with him in the business Thomas H. Powers and his nephew, William Weightman, under the firm name of Farr, Powers & Weightman. After the decease of Mr. Farr in 1847, the firm became Powers & Weightman. Since that time the business of the firm has extended enormously. Since his two sons died, years ago, his only surviving child is Mrs. Anne M. Walker, who is now the only member of the firm of Powers & Weightman.

DIGEST OF U. S. PATENTS

Prior to July, 1902.

Compiled by Byrnes & Townsend,
Patent Lawyers,
National Union Building, Washington, D. C.

Electrolysis of Molten Sodium Salts.

(*Continued from page 334.*)

623,691, April 25, 1899, Charles E. Acker, East Orange, N. J.

Electrolyzes molten sodium chloride on a cathode of molten lead. The cell comprises an annular electrolyzing chamber with magnesia walls; a central alloy-receiving chamber with a wrought-iron partition wall jacketed with magnesia, and a cast-iron bottom, with a central outlet from the alloy chamber to the outer bottom edge of the electrolyzing chamber, and an annular passage below the partition wall. A screw in the central outlet forces the depleted lead from the central chamber out under the molten salt in the annular chamber, where it receives more sodium and returns beneath the partition to the alloy chamber. The richer, lighter alloy rises to the top of this chamber and passes down through an escape pipe, but part of the sodium vaporizes and escapes through an upper passage to a condenser, the movement of the sodium vapor being facilitated by a current of nitrogen derived from the deoxidized air in the apparatus. The nitrogen is returned from the sodium condenser to the alloy chamber. The proportion of vaporized sodium may be increased by keeping the alloy at a higher temperature. The connection to the lead cathode may be constructed as a heater, a resistance rod of carbon being protected by an iron sheath. Lead is supplied to the cathode from a separate pot. The cell is closed by a tile cover which supports the salt supply. The preheated salt is fed through holes having stoppers; it serves to seal the joints between the cover and the carbon rod anodes.

623,692, April 25, 1899, Charles E. Acker, East Orange, N. J.

Same apparatus as in preceding patent. Tin or zinc may be substituted for lead, as cathode. May treat the alloy with steam or air.

649,565, May 15, 1900. Charles E. Acker, East Orange, N. J.

Electrolyzes molten sodium chloride on a thin layer of lead, as cathode, flowing from an inlet at one side of the bottom of the cell to an outlet at the other side. At one end of the cell is a well which receives the products and returns the depleted lead to the cell. The sodium is oxidized by injecting steam either into the passage which conveys the alloy to the well, or into the well itself. The cell is a cast-iron vessel lined at the sides with magnesia. It has a fire clay cover with holes and two-part rings receiving the carbon rod anodes. The supply of salt rests on the cover and is fed in through stoppered holes. The modified cell employing an oxidizing well delivers alloy to the lower end of the well and receives the depleted lead from its upper end. A steam pipe depends nearly to the bottom of the well, and the rising steam oxidizes the sodium, thus supplying heat, and effects the circulation of the lead. The molten caustic overflows from the upper end of the well into a packing drum. When oxidation is effected by injecting steam into the passage which delivers alloy from the cell, the well is used as a settling chamber. The hydrogen may be burned to melt salt in a separate vessel.

663,719, December 11, 1900, Hermann Becker, Paris, France.

Electrolyzes molten compounds of light metals. The cell is a metal vessel having a tubular bottom extension in which is a sleeve of lava, porcelain or fire clay, receiving the terminal stem of the metal cathode. The extension is surrounded by a water-jacket, which produces a plug of solidified electrolyte to prevent leakage around the stem. The cathode consists of one or several upwardly-tapering bars, from which the deposited metal easily detaches itself and rises into a conical air- or water-cooled collector above. This collector is of metal and is constituted a supplemental cathode by a high-resistance shunt connection. The metal is delivered through a lateral pipe. The anode is a ring of carbon or metal, surrounding the cathode.

674,691, May 21, 1901. Charles E. Acker, Niagara Falls, N. Y.

The apparatus of his prior patent, 649,565.

679,253, July 23, 1901, Alfred H. Cowles, Cleveland, Ohio.

Electrolyzes compounds of volatile elements, *e. g.*, sodium, potassium, zinc, phosphorous. The cell is an iron vessel, the sides of which are lined with the solidified electrolyte. The false bottom and cathode is a horizontal plate of porous carbon, below which is a condensing and collecting chamber. The element deposited on the cathode vaporizes and passes through it and is collected below. For the production of sodium, may use a haloid salt or a mixture of sodium fluoride and aluminium fluoride, to which may be added sodium carbonate. The oxidation of the carbon anode may produce sufficient electrical energy to effect decomposition, the dynamo simply raising the potential to a point sufficient to overcome the resistance of the electrolyte and maintain it molten. A cell having twenty carbon anode rods, each 2½ inches in diameter, requires 3000 amperes at 5 volts. The cathode plate is preferably a baked mixture of coke and coal tar or pitch.

687,709, December 3, 1901, Charles E. Acker, Niagara Falls, N. Y.

Electrolyzes molten sodium chloride in a cell having a molten lead cathode and a separate, oxidizing well receiving a jet of steam. The cell is similar to that of his patent 649,565, except that the well has a screw on a central shaft, to control the circulation of the lead, which is effected in part only by steam injected through two pipes, one entering horizontally, the other upwardly.

Electrochemical Industry

VOL. II. NEW YORK, OCTOBER, 1904. NO. 10.

Electrochemical Industry

Published on the first of each month by the
ELECTROCHEMICAL PUBLISHING COMPANY,
[Incorporated.]
114-118 LIBERTY STREET, NEW YORK.

J. W. RICHARDS, PH. D. .....*President.*
E. F. ROEBER, PH. D. .....*Editor.*

Telephone Call: 7607 Cortlandt.

Subscription Price: $2 per year, postpaid to any part of the world. Single copies 25 cents.

ADVERTISING RATES GIVEN ON APPLICATION.

Copyrighted, 1904, by the Electrochemical Publishing Co.

Entered as Second-Class Matter, June, 1903, at the Post-Office at New York, N. Y., under the Act of Congress, March 3, 1879.

Editorial 385
Society of Chemical Industry 388
The Chemistry of Electroplating. By W. D. Bancroft 389
Differences in the Electrolysis of Potassium and Sodium Chloride. By F. Winteler 391
Electrolysis and Catalysis. By W. Ostwald 393
The Manufacture of Ferro-Alloys in the Electric Furnace. By G. P. Scholl 395
Electrochemistry at the International Electrical Congress of St. Louis 397
T. W. Richards on the Relation of the Hypothesis of Compressible Atoms to Electrochemistry 397
J. S. Edstrom on Electrical Extraction of Nitrogen from the Air 399
F. Haber and L. Bruner on the Carbon Cell 401
L. Kahlenberg on the Electrochemical Series of Metals 402
A. G. Betts and E. F. Kern on the Lead Voltameter 403
J. Swinburne on Chlorine in Metallurgy 404
H. Goldschmidt on Alummothermics 404
K. F. Guthe on the Silver Voltameter 406
H. S. Carhart and G. A. Hulett on Materials for Standard Cells 407
P. L. T. Héroult on Electrometallurgy of Iron and Steel 408
A. E. Kennelly and S. E. Whiting on the Edison Storage Battery 409
J. W. Richards on Electrolytic Conduction 411
R. Lorenz on Electrolysis of Fused Salts 412
H. E. Patten on Deposition of Aluminum from Ethyl Bromide Solutions 413
W. D. Bancroft on Aluminium Rectifiers 413
W. McA. Johnson on Some Aspects of Applied Electrochemistry 414
F. A. J. FitzGerald on Testing the Temperature in Electric Furnaces 415
W. D. Bancroft on Electrolytic Separation of Cobalt and Nickel 415
Notes on Papers on Electrochemical Subjects before other Sections of the Congress 416
New York Meeting of the Society of Chemical Industry 417
Sir William Ramsay on the Training of Technical Chemists 417
Chamber of Delegates, International Electrical Congress, St. Louis, 1904 419
Cost of Electric Power Used in Electric Reduction Works. By Louis Simpson 421
Correspondence: Solubility of Gold. By C. J. Reed 422
Analysis of Current Electrochemical Patents. By George P. Scholl. 423
Synopsis of Articles in Other Journals 426
Recent Metallurgical Patents 429
Book Reviews: Classen, Quantitative Chemical Analysis by Electrolysis 431
Pyrometers Suitable for Metallurgical Work 431
Suction Gas Producers 432
Industrial Notes 433
Personal 434
Digest of United States Patents, Prior to July, 1902. By Byrnes & Townsend (Electrolysis of Molten Sodium Salts; Molten Electrolytes, Miscellaneous) 434

ELECTROCHEMISTRY AT THE INTERNATIONAL ELECTRICAL CONGRESS OF ST. LOUIS.

The Electrical Congress, held at St. Louis from September 12 to 17, was the fifth of international electrical congresses, but it was the first one of such bodies at which electrochemistry was adequately represented. It is not that electrochemical engineering is so young that it could not have been represented as such on former congresses—storage battery engineering and electrolytic copper refining are as old as dynamo construction. But in the past the engineers and scientists working in the field of electrochemistry were scattered, and, in this country at least, electrochemistry as an organized profession, with a fully developed esprit de corps, dates only from the organization of the American Electrochemical Society. The great success of the St. Louis Congress in general—which surpassed all former electrical congresses by the number of those who enrolled as members, by the number of those who attended it, and by the number of excellent papers presented—this success is due largely to the splendid and careful work of the Organization Committee and its indefatigable chief officers, Prof. Elihu Thomson, Dr. A. E. Kennelly and Mr. W. D. Weaver, and to the shrewd policy by which all the national electrical engineering societies of this country were enlisted as co-workers for the success of the Congress. To the co-operation of the American Electrochemical Society is largely due the success of the electrochemical section of the Congress. As was already noticed in these columns, the American Electrochemical Society decided to hold its regular autumn meeting in connection with the Congress, but to hold only one independent session, and to spend all surplus energy to further the success of Section C of the Congress. Thus, there was a most intimate connection between Section C and the American Electrochemical Society; only somebody most thoroughly initiated would have been able to tell at any moment whether he was attending a meeting of Section C or of the Society or a joint meeting. Under these circumstances we have thought it best to give a full account of the doings of both Section C and of the Society in one single report under the title Electrochemistry at the International Congress of St. Louis. This report will be found on other pages of this issue.

The way in which electrochemistry was represented, was most gratifying. Section C was one of the most international sections of the Congress. Of course Americans largely prevailed among the authors of papers, but there were also represented Germany, France, England, Sweden and Switzerland. Moreover, the programme was well-balanced, the numbers of engineering and scientific papers being about equal. This was due to the fact that the Congress papers were specially invited from authors in many countries, instead of being volunteered from members of a national society only. The fact

that the Congress was held in a World's Fair city, had both advantages and disadvantages. Undoubtedly, many were thereby induced to attend the Congress, who would have hesitated otherwise. On the other hand, many who pretended to have come to attend the Congress were rather visitors at the Fair. One of the worst disadvantages was the location of the Congress headquarters in the business district in the southern part of the city, while the Fair is held in the far northwest; traveling to and fro in a crowded street car is anything but delightful. The counter attractions afforded by the Fair and by the other sections of the Congress, caused the attendance in any single section to be less than is usual in meetings of our national engineering societies. This was the same in Section C, as in all other sections. The only session of Section C which drew a large audience was the special session, at which Dr. H. Goldschmidt delivered his lecture on aluminothermics; but this session was held in a hall on the Exposition grounds, and during evening hours, when there were no other section meetings. While the relatively small attendance at the various sessions impaired somewhat the value of the discussions, yet the work and the importance of the Congress is rather determined by the value of the papers themselves which were presented. There can be no doubt that in this respect the Congress was an even greater success than its most enthusiastic promoters had anticipated.

Among the papers on industrial electrochemistry and electrometallurgy, Dr. P. L. T. Héroult's paper on the use of the electric furnace in the iron and steel industries deserves the full interest of both manufacturers and users of steel. Dr. Héroult refers briefly to the reduction of iron ores in the electric furnace, but the main point of the paper is his advocacy of the electric furnace for steel refining, as an adjunct to existing steel plants; he claims that at a cost of not more than 50 cents per ton, any steel, delivered in molten state, such as tapped out of a Siemens furnace or obtained from a Bessemer converter, can be converted into steel of any desired composition, containing not more than 0.01 sulphur and 0.01 phosphorus. It is to be taken into consideration that it is Dr. Héroult who makes this claim, and that he makes it on the basis of his experience obtained in two years' working of his process on a commercial scale. The conclusion which he draws is obvious: it is that while the electric furnace may not revolutionize the metallurgy of iron and steel, yet it will so cheapen the production of those at present very expensive finest grades of steel that they will come into more and more extended use in the near future. Dr. Hans Goldschmidt's lecture on aluminothermics did not reveal any new principles of his well-known method, but many details on the increasing use of this method in various industries, of which the applications of the box reaction in foundry practice are most interesting; a promising new development for various chemical industries is the treatment of the aluminium oxide slag with a binding material for the manufacture of chemical apparatus and vessels with practically zero coefficient of expansion.

Mr. J. S. Edstrom's paper brought a subject to the front which has attracted many inventors in recent years—the fixation of atmospheric nitrogen. The feature of the process of Birkeland and Eyde, described by Mr. Edstrom, is that in the rapid production and interruption of arcs passing through the air to be acted upon, the familiar phenomenon of the deviation of the arc by a magnetic field is made use of. The chief advantages claimed for this method are that one is not restricted in the amount of electric power used and that the wear and tear of the apparatus is small. Some details in Mr. Edstrom's paper are very interesting, but the information given is not yet sufficient to form a conclusive idea on the economy of the operation of the process. Mr. James Swinburne's paper on chlorine smelting records an interesting application of the non-electrochemical part of his process by the (British) Castner-Kellner Company. Of course, the purpose of this company is to make good use of their electrolytic chlorine; they could, therefore, not use the Swinburne process as a whole in which the chlorine passes through a cycle, and in which no new chlorine is required, except for making up the unavoidable losses. They therefore stop with the production of zinc chloride, which is sold.

Prof. A. E. Kennelly and Prof. S. E. Whiting presented, in behalf of Mr. T. A. Edison, a paper giving the results obtained with his nickel-iron storage battery up to the present date. The point emphasized by the authors is that in the Edison battery we have for the first time a steel structure for an electrolytic process which, with respect to the figure of watts per pound, is comparable to the steel structure of dynamos. A very interesting paper by Mr. F. A. J. FitzGerald dealt with the use of samples of carbon for determining the temperature within an electric furnace; this method is based on the fact that the determination of the density of carbon can be used for estimating the temperature to which it was subjected. By placing a number of samples of carbon at different points within a furnace, it is thus possible to find whether the distribution of the temperature throughout the furnace is as desired; for instance, whether it is uniform, if this is wanted. It becomes more and more necessary to use all possible skill in the design of electrical furnaces in order to utilize them to the best advantage, and a simple means, like that of Mr. FitzGerald, to find out whether a furnace design is what it is intended to be, should be most valuable. A paper of Mr. W. McA. Johnson gave interesting general points of view on industrial electrochemistry; any engineering process is intended—in the last resort—to make as much money as possible, and any electrochemical method, if used as part of a chain of metallurgical operations, should be so devised that the efficiency of the whole chain is a maximum.

Among the purely scientific papers, one by Prof. T. W. Richards gives a very interesting outline of the very wide field of electrochemical and electrical phenomena, to which the view point of his hypothesis of compressible atoms may advantageously be applied, although it is avowedly still nothing more but a hypothesis. A paper by Dr. Louis Kahlenberg gives interesting results on very extended experimental researches on potential differences of metals in various solvents, the main point being the proof that a slight change in the composition of the solvent may change the order of the metals in the electrochemical series. The importance of the

establishment of these experimental results will not be denied by anybody, though it may be doubted that they refute the fundamental assumptions of Nernst's theory of solution tension, as Dr. Kahlenberg appears to assume. It is true that the solution tension of a metal has often been assumed to be independent of the solvent, but there is no necessity for such an assumption, if one critically reviews the thermodynamical reasoning on which Nernst's formula, containing the solution tension, is based. In a paper on the mechanism of the conduction of an electric current through electrolytes Dr. J. W. Richards offers a thesis which is radically different from the views generally held. He suggests that the conduction of the current through the interior of an electrolyte is not different from the conduction of the current through a metal and that this conduction should be carefully differentiated from the chemical phenomena of oxidation and reduction, taking place at the electrodes. There was a lively discussion of this paper and the experiment quoted by the author as confirmation of his theory was not considered as convincing. However, any theory is in reality nothing but a description of facts, and if Dr. Richards could develop his theory, so that it fully describes all the facts, it would be just as good as the model of ions. But it seems rather doubtful whether the theory could be so developed as to cover, for instance, Kohlrausch's law of the independent movement of the ions in very dilute solutions, which represents an experimental fact and is very easily described by the model of ions.

Of the papers on the border line between electrochemical science and industry, those of Prof. W. Ostwald on electrolysis and catalysis, and Prof. W. D. Bancroft on the chemistry of electroplating, were specially interesting, and are, for this reason, printed in full in this issue. But both papers are markedly different from each other in one respect. In Prof. Ostwald's paper we are confronted rather with a theory, than with a condition; he gives a theory of what might be done, and, perhaps, will be done; the paper is certainly highly suggestive. In the case of electroplating we are confronted by a condition—a mass of experimental facts, found in the practical working of many years by the cut-and-try method—while a theory which combines all these single facts is missing. Prof. Bancroft made the praiseworthy attempt to lay the keystones of such a theory. Prof. F. Haber and Dr. L. Bruner gave a new theory on the action of the Jacques carbon cell; while the explanation given by the authors is absolutely novel, yet the practical result is the same as that of former investigators of this cell—namely, that the cell is without value for the practice. Prof. R. Lorenz gave an interesting summary of the extended researches, made in his laboratory on the electrolysis of fused salts. The silver voltameter was the subject of a paper by Dr. K. E. Guthe, while Mr. A. G. Betts and Dr. E. F. Kern proposed the lead voltameter for commercial purposes—the latest outcome of the Betts lead refining process. Prof. H. S. Carhart and Dr. G. A. Hulett presented the latest results obtained in their investigation of the cadmium standard cell, with electrolytically prepared mercurous sulphate. The aluminium rectifier was the subject of two papers—one by Dr. Bancroft, the other (in section B) by Mr. Nodon. Dr. H. E. Patten's paper on the deposition of aluminium from ethyl-bromide solutions was specially interesting on account of the use of a non-oxygen containing electrolyte on the basis of the theory that the difficulty of getting an aluminium deposit is due to its immediate re-oxidation. Truly, this brief outline will show that Prof. H. S. Carhart was right, when, as the chairman of Section C, and as president the American Electrochemical Society, he congratulated the members on the character and variety of the papers presented.

THE PROPOSED INTERNATIONAL COMMISSION ON UNITS.

Before the International Electrical Congress met in St. Louis, the fear was expressed repeatedly in various European countries that hasty resolutions would be passed concerning units and standards. It was assumed to be due to such suspicions that England, France and Germany were slow to appoint official delegates. However, England and France, in the eleventh hour, gave official recognition to the Chamber of Delegates, while even Germany recognized it to a certain extent by appointing a single delegate, but without authority to vote on questions of units and standards. However, the proceedings at St. Louis will now convince everybody that all previous fears and suspicions were groundless. In the first place, it had never been the intention to bring the questions of units and standards before the general membership of the Congress; considerations of this kind were reserved to the "Upper House," the official Chamber of Delegates, appointed by the various countries. Moreover, the Chamber of Delegates eventually did not take any action whatever on any proposition brought before the Chamber with respect to changes in present standards or units or additions thereto. But the Chamber of Delegates did something which, we are sure, will turn out to be of far greater importance in future. In a resolution, printed on another page of this issue, it formulated a plan for the appointment of a standing international commission on units, to be named by the different governments, for consideration of all matters relating to electrical units, standards, notation, nomenclature and other matters concerning which it is desirable to have international uniformity.

It seems not too sanguine a view to hope that favorable action on this plan will be taken, since the delegates of the St. Louis Chamber will urge it on their governments. The result would be far-reaching. In the first place it would put an end to chambers of delegates sitting in connection with international congresses; undoubtedly this system had distinct disadvantages. Moreover, we may hope that the commission may eventually become a permanent one. Of course, much will depend on the gentlemen chosen for the commission. If the commission shall really further engineering and industries, it should consist rather of representatives of the profession, and not of bureaucrats. While electrochemical units are not specially mentioned, they would undoubtedly fall within the field of the commission. In this connection we may point out that the next International Congress for Applied Chemistry, to be held in Rome in 1906, intends to take up this question. It is surely in the interest of electrochemistry if the question is not taken up by a chemical or by an electrical congress, but by a commission of the kind which is planned.

SOCIETY OF CHEMICAL INDUSTRY.

A report of the general annual meeting held at Columbia University and an abstract of Sir William Ramsay's presidential address on the Training of Technical Chemists, will be found on another page of this issue. The rest of the programme for the days while the foreign guests stayed in New York City was carried out in accordance with the arrangements which had been most carefully planned. The result was correspondingly a huge success. Since the programme was published before in our columns we may simply mention that the roof garden reception at the Majestic Hotel was made impossible on account of the inclement weather, so that the reception had to be held indoors. The smoker and vaudeville entertainment at the Liederkranz Hall on Saturday night was a very enjoyable affair. Dr. H. Schweitzer presided over the smoker which was carried out in form of a German Kommers. A most numerous Kneipzeitung had been prepared. Sir William Ramsay presented an address of thanks signed by the European guests.

On Saturday afternoon, before the smoker, the members of the committee and several Europen guests were received by President Roosevelt at Oyster Bay.

Annual Banquet.

The banquet held on Thursday evening at the Waldorf-Astoria was most notable, on account of a series of excellent speeches. Dr. Charles F. Chandler, acted as toast-master, and was very happy and pertinent in introducing the various speakers. He first proposed the health of the President of the United States, which was drunk standing, and the health of his Majesty, King Edward, which was also drunk standing. Dr. Chandler, in announcing that the next toast would be the Society of Chemical Industry, called for a response from the retiring president of the society, and introduced Sir William Ramsay, with the remark that Sir William owed the society an apology for bringing into the chemical elements a lot of tramps, by his discovery of five of the laziest elements, like argon, about which nobody has ever heard a good word.

Sir William Ramsay, in responding to the toast said that by his presidential address he had hoped to bring in closer touch science and industry, and he expressed the hope that the new president, Dr. Nichols, would look at the other side of the sheet in his address next year and touch upon the relation of industry to science. He confessed to having been blamed for bringing into the world a set of lazy children—although there was a sort of step-father for one of them—and added that a new chemical child was born about two months ago, and that recent experiments had given him the hope that we may now find out the source of the ordinary chemical elements. It was a mere hope, however, so far. He expressed the hope that the union between the United States and Great Britain in the Society of Chemical Industry would last forever.

Dr. Chandler said that there is a society known in New York as Verein Deutscher Chemiker, which usually meets after the Society of Chemical Industry has met and brought forth and illustrated the latest developments of science; then tables are brought in, and the spigot is driven into a barrel and beer is circulated; then they say the Verein Deutscher Chemiker is in session. As an extraordinary envoy of this Verein he introduced Dr. H. Erdmann, of Charlottenburg, who, in his reply expressed the wish that in the chemical union between the United States and Great Britain, Germany might be the third party. A toast to the Verein Deutscher Chemiker was then drunk.

In proposing the next toast on industrial corporations, Dr. Chandler said the only person they could find with a corporation was Dr. H. W. Wiley, and this was probably due to his extended experiments with all kinds of poisons as food. Dr. Wiley, in responding, said that there is no danger of a dissolution of the union of the British and American members of the Society of Chemical Industry. He referred to a little fact in history; namely, that the United States parted from England because they were taxed without representation. But that is not so in the Society; "you tax us, it is true, but look at the representation which we have." So there is going to be no Boston Tea Party in the Society of Chemical Industry. There is a perfect community of interests. International meetings do more to draw together already strong ties than any amount of preaching in public prints can do. One sees one's fellow man face to face and begins to appreciate that after all it is the man as a man. In the great sphere of industry, it is the man who does things. We measure the man by the industry, but the man is the thing. Industry is incident to the man and his development, and it is because industries develop manhood and not because they bring dollars, that industries are useful to man.

Dr. Wilhelm Ostwald spoke of the international character of science. Science is the only thing which forms a part of the equipment of every human being which has reached some degree of civilization. He alluded to his latest favorite idea—that people in all countries might learn a universal language. He drank his glass to the furtherance of the idea of international brotherhood. "Science is brotherhood."

Dr. William H. Nichols, replying to the toast on American Chemical Industries, said that to pay the workingman well is an effective means of cheapening the cost of the product. In recalling names of pioneers in American chemical industries he referred to Mr. Weightman, of Philadelphia, who recently died, Mr. Martin Kalbfleisch and others, while the future of industrial chemistry in this country is in the hands of the young men. As a representative of the British Consul, Mr. K. Bailey spoke of his impressions of New York. As a representative of the English committee who arranged the trip, Mr. Thomas Tyrer spoke of the splendid hospitality of the New York Section and paid a glowing tribute to the ladies' committee. The last speech was made by Dr. Hugo Schweitzer, who was godfather when the New York Section was founded. He went into the history of the growth of this section. As chairman of the general committee of arrangements he expressed his thanks to Drs. Coblentz, Moore, Mr. Zabriskie and Drs. Parker and Love. The last two he called the "gold dust twins," they having looked after the financial end of the matter.

Tour Through the United States.

The tour through the country was carried out according to the programme, which has been printed before in these columns. The special train was provided with all possible comforts, bathrooms, barber shop, barroom, observation cars; even a stenographer and typewriter was present. In Philadelphia at the dinner at the Germantown Cricket Club, Dr. S. P. Sadtler, as chairman of the local committee, spoke some well-chosen words of welcome; Sir William Ramsay replied in his characteristic humorous mood and expressed the thanks of the guests for the splendid hospitality, while Mr. C. G. Cresswell gave an outline of the history and growth of the society. The reception of the society in Washington was equally splendid; the beauties of the city were greatly enjoyed, though inclement weather spoiled somewhat the trip to Mount Vernon.

The programme for Pittsburg was most extensive and well arranged, and the numerous visits to plants and works were extremely enjoyed. At the luncheon in the Union Club, Sir William Ramsay paid a well-earned tribute to the work of the local committee and its chairman, Mr. K. F. Stahl.

In St. Louis the programme had been so arranged that as much time as possible was at the disposal of the visitors to see the World's Fair and to attend the Congress of Science and Arts. But at the time when these notes were prepared for the press, no further details were available.

THE CHEMISTRY OF ELECTROPLATING.[1]

By Prof. Wilder D. Bancroft.

Although some results have been obtained by Mylius, Foerster, Glaser, Burgess and others, a glance at the recent text books on electrochemistry will show how far we still are from any consistent theory of electroplating. The reason for this is to be found in our neglect of the chemistry involved. The electric current is merely one agent for bringing about certain chemical reactions; but this is often overlooked, and many of us consider a decomposition by means of electricity as much more mysterious than a decomposition by heat, for instance. I hope to show that a study of chemical reactions and chemical analogies will at least give us the outlines of a theory of electroplating.

When we speak of a good metallic deposit, we may mean good from the point of view of the analyst, the refiner, or the plater. The analyst must have a deposit of pure metal in a weighable form, but that is all. The refiner must have a coherent deposit of pure metal, except in the case of silver. Neither the analyst nor the refiner cares about the smoothness of the deposit, so long as no trees are formed. The plater must have an adherent smooth deposit which will burnish to an apparently amorphous surface. In the preliminary discussion we will rule out the plater and will call a deposit good when it is pure and coherent. Afterward we can consider the further problem of the production of a very fine-grained deposit. Since there are very few data for anything except aqueous solutions, we will consider these only, though the general principles are equally applicable to all solvents.

When working with moderate current densities, a bad deposit is practically always due to the precipitation of a non-metallic solid with the metal. When one of the single salts in the bath is sparingly soluble, as with the cyanides, the salt may precipitate. In most cases, however, the trouble is due to the presence in the deposit of oxygen either as oxide, hydroxide or basic salt. Whatever will dissolve the salt readily under the conditions of the experiment will prevent its deposition, and should therefore improve the quality of the deposit. This has been recognized for zinc by Mylius and Fromm[2] and by Foerster and Guenther.[3] It has been put in a more general form by Glaser.[4]

I have made a list of the more important additions recommended in the refining, analysis, or plating of zinc, nickel, lead, tin, copper and silver. These are given in Table I.

Table I.

Zinc.	Tin.
Sulphuric acid.	Sulphuric acid.
Potash.	Potash.
Ammonium chloride.	Sodium pyrophosphate.
Ammonium sulphate.	Potassium carbonate.
Aluminium sulphate.	Acid potassium tartrate.
Potassium cyanide.	Potassium cyanide.
Acid potassium oxalate.	
Nickel.	**Copper.**
Sulphuric acid.	Sulphuric acid.
Ammonia.	Ammonia.
Ammonium salts.	Alkaline tartrate.
Potassium cyanide.	Ammonium oxalate.
Sodium bicarbonate.	Potassium cyanide.
Sodium bisulphite.	Sodium bisulphite.
Lead.	**Silver.**
Acetic acid.	Nitric acid.
Potash.	Ammonia.
Fluosilicic acid.	Potassium cyanide.
Sodium nitrate.	Potassium iodide.

All the substances under zinc dissolve zinc hydroxide. The first four under nickel dissolve nickel hydroxide; the sodium bicarbonate probably serves to keep the acidity constant; while the sodium bisulphite occurs only in solutions containing free ammonia. All the substances under lead dissolve lead hydroxide. Stannous and stannic acids are soluble in suphuric acid, in potash, and in a so-called sodium pyrophosphate solution; potassium carbonate is added only to neutralize an excess of free acid in stannous chloride solutions; while the cyanide and tartrate seem to be of very little value, unless, perhaps, at the anode. Under copper everything dissolves the hydroxide except sodium bisulphite and this is added to cyanide solutions to prevent loss of cyanogen when the copper changes from the cupric to the cuprous form. All four substances under silver dissolve freely-precipitated oxide; in addition ammonia dissolves silver chloride, while cyanide and silver iodide are soluble in potassium cyanide and potassium iodide respectively.

It is thus clear that there is a simple rational basis for many of the solutions in actual use. It must be kept in mind, however, that the rate of solution is more important than the actual solubility. Thus it is not easy to get a good solution from an alkaline zincate solution at 20° C., whereas it is a comparatively simple thing to do this at 40°, because the caustic soda reacts with zinc oxide or hydroxide much more rapidly at this temperature. It does not follow from this that a higher temperature would necessarily be even better. At 90° the action of caustic soda on metallic zinc becomes an important factor. With copper sulphate solutions rise of temperature means increased formation of cuprous sulphate, and this must be taken into account. In each of these cases a study of the chemical reactions shows the cause of the difficulty.

While there is much evidence in favor of Glaser's first generalization, that a metallic deposit is improved by adding to the solution substances which will dissolve the oxide, hydroxide or basic salt, there are only a few scattered experiments which can be cited in favor of Glaser's second generalization that reducing agents improve the quality of the deposit. Glaser[5] observed that addition of pyrogallol or hydroquinone to a lead bath improved the deposit of electrolytic lead. Engels[6] states that the addition of hydroxylamine makes it possible to use higher current densities in the analysis of copper. It is believed that tin salts in solution improve the quality of a copper deposit[7], and it is known that ferrous salts are not disadvantageous. Good deposits of many metals are obtained from cyanide solutions and part of the effect, though certainly not the whole of it, may be due to the fact that potassium cyanide is a reducing agent. It is also possible that the merits of a tartrate solution may be due in part to the formation of reducing agents by oxidation at the anode.[8] In some experiments made at Cornell we have found that hydrazine improves the electrodeposition of cobalt and that resorcin has a slight favorable effect with zinc, but apparently not with tin. The negative result in this last case may be due to the reducing power of the tin solutions. These instances will suffice to show that we do not yet know definitely how much influence a reducing agent has or how it varies with varying conditions. Since none of the reducing agents in question will reduce the oxide to metal, it seems very probable that the effect of the reducing agent may merely be to prevent oxidation by dissolved oxygen. If so, the effect should disappear in a vacuum or in an atmosphere of nitrogen. It has not yet been possible to try this experiment.

We have next to consider the effect of higher current densities. When solutions are not stirred we soon reach a point at which an ever-increasing density causes a bad deposit. This change in the quality of the deposit is always accompanied by

[1] A paper read at the International Electrical Congress in St. Louis. This is one of the three papers presented by special delegates of the American Electrochemical Society to the Congress.
[2] Zeit. f. Anorg. Chem., 9, 144 (1895).
[3] Zeit. f. Elektrochemie, 5, 16 (1898); 6, 301 (1899).
[4] Zeit. f. Elektrochemie, 7, 365, 381 (1900).
[5] Zeit. f. Elektrochemie, 7, 381 (1900). Cf., Elbs and Rixon. Ibid. 9, 267 (1903).
[6] Smith. "Electrochemical Analysis," 62.
[7] Borchers. "Elektrometallurgie," 193.
[8] Luther. Zeit. f. Elektrochemie, 8, 647 (1902); Schilow. Zeit. f. Phys. Chem., 42, 646 (1903).

an increased evolution of hydrogen, and it is usually believed that the evolution of the hydrogen is the cause of the deposit going bad. This cannot be the whole truth, because hydrogen is evolved freely during electrolytic analyses, and yet the deposit remains good. Further, the so-called critical current density varies enormously with the size, shape and distance apart of the electrodes, and also with the size and shape of the containing vessel, so that the data obtained by any one man usually cannot be duplicated by others. The most important factor is the rate of stirring. If we rotate a smooth copper, zinc or nickel cathode with sufficient speed, it is by no means certain that there is any current density at which the deposit goes bad. With tin there does seem to be a limiting density, but this is very possibly due to the formation of stannic salts in solution. It is intended to study this question in detail.

When a deposit becomes sandy or changes to a black powder, the polarization shows that there has always been the formation of a dilute solution at the cathode. In most cases this leads to the precipitation of an oxide or a basic salt with the usual disastrous results. It is still an open question whether this is always the case. Foerster and Seidel[9] say that sandy deposits of copper are not due to the presence of oxide. If this statement is correct, we shall be forced to the assumption that the badness of the deposit is due to the pulsating or intermittent precipitation of hydrogen as a result of the intermittent formation of a surface film impoverished as to metal. This explanation does not appeal to me personally and I prefer to believe for the present in the oxide formation, even if I have to account for the apparent absence of hydrogen by assuming a reduction to metal after the harm has been done.

Hydrogen may easily be indirectly the cause of a bad deposit. If hydrogen adheres as bubbles to the cathode, the deposition of the metal will become uneven and we shall have conditions favorable for treeing. A trouble of this sort can be cured chemically by adding an oxidizing agent to remove the hydrogen. It is known that copper solutions containing nitric acid will stand much higher current densities than will those acidified with sulphuric acid. It is clear that the prevention of hydrogen by means of an oxidizing agent may lead to the oxidation of the metal, in which case we are out of the frying-pan into the fire. Foerster and Guenther[10] had difficulties with hydrogen bubbles during the precipitation of zinc. They show that such oxidizing agents as chlorine and ammonium persulphate prevent the appearance of hydrogen without causing the formation of zinc oxide. Such oxidizing agents as hydrogen peroxide and ammonium nitrate prevent hydrogen evolution, but were worthless because they oxidized the zincs.

An oxidizing agent could probably be used to prevent occlusion of hydrogen by nickel, for instance. It is quite likely that the disadavantages would outweigh the advantages. In that case it would be better to approximate the same result by varying other conditions. The favorable conditions would be: a concentrated solution to ensure a good deposit; a high temperature to lower the absorption coefficient; a nearly neutral solution to increase the decomposition voltage of hydrogen; and a high current density to give a fine-grained metal. For any given rate of stirring we should expect a limiting current density beyond which deterioration would occur. With increasing current density we get a finer deposit, but there is also an increasing tendency to precipitate hydrogen, and it is necessary to strike a balance between these two. All these conditions have been found experimentally for nickel by D. H. Browne[11], with the one exception that he finds a large addition of sodium chloride advantageous. The reason for this is not clear.

Having considered the conditions for getting a good deposit from the refiner's point of view, we can now take up the question from the point of view of the plater. The problem is now as to the conditions under which the deposit is composed of very small, microscopic crystals.

When we precipitate a salt by chemical means we get larger crystals, the slower the precipitation and the higher the temperature. We should, therefore, expect that an electrolytic deposit will be coarser the lower the current density and the higher the temperature, provided all other conditions are held constant. The conclusion as to the current density is confirmed by all experiments. The case of the temperature change is a little more complicated, because we may have hydrolysis and increasing acidity or alkalinity; we may have increased solvent action, and we may have a displacement of equilibrium as with copper sulphate. The effects due to these changes will, of course, superimpose themselves on the pure temperature effect and mask or even reverse it. In some experiments, made in my laboratory, Mr. Enowdon found that the deposit from an acidified copper sulphate solution became coarser as the temperature was raised from 20° to 40° and to 70°. A similar result was obtained with a strongly acid zinc sulphate solution and with a lead bath. With nickel ammonium sulphate solution the effect of temperature on the crystalline structure of the deposit was too small to be detected. With a zinc sulphate solution which was only slightly acid, the deposit was more finely-grained at 40° than at 70°; but the deposit at 20° was coarser than either of the others. I suspect that at 20° the slight acidity had no appreciable effect on the deposit, while it became an important factor at 40°. This hypothesis is confirmed by the other experiment in which a more acid solution behaved normally.

For a given current density, temperature and salt solution, we should expect a coarser-grained deposit the more concentrated the solution. This has been found to be the case in experiments with zinc sulphate, and sodium zincate solutions. Since the potential difference between the metal and the solution is less the more concentrated the solution, it seems probable that this is an important factor when we change from one solution to another. Other conditions being the same we shall get the smallest crystals, the greater the potential difference between the metal and the solution. This is the recognized explanation for the excellent character of the deposits from cyanide solutions.

A natural corollary from this last is that the deposit will be more finely crystalline, the greater the solvent action of the solution. This accounts for the small crystals that are obtained from an acid copper sulphate solution or from one containing nitric acid. This conclusion, of course, holds only within the limits for which we get a good deposit. The converse of this would be that reducing agents should increase the size of the crystals. Mr. Snowdon has found that addition of formaldehyde to a copper or a zinc solution does make the deposited metal more coarsely crystalline. Resorcin has a similar effect with zinc. It will be difficult to get conclusive evidence on this point, because many reducing agents form complex salts and the effect due to this may easily overbalance the other. If the reducing agent acts only to remove dissolved gases, its effect on the size of the crystals would probably be negligible.

The addition of glue or similar substances to a solution tends to make precipitates come down in a colloidal form. Following out this analogy, we should expect to find that addition of glue or similar substances to an electrolyte bath would decrease the size of the metal crystals, the limiting concentration being that at which the added substance causes a bad deposit owing to its chemical properties. It is known that the success of the Betts process for refining lead is due in part to the action of glue in preventing trees. We have found that the addition of ten grams of glue per liter of acidified copper sulphate solution improves the quality of the deposit from the plater's point of view.

One final point is of importance to the plater, the adhesion of the deposit. It has been suggested that an adherent plating deposit can be obtained only when the two metals can com-

[9] Zeit. f. Anorg. Chem., 14, 125 (1897).
[10] Zeit. f. Elektrochemie, 5, 22 (1898).
[11] Electrochemical Industry, 1, 318 (1903).

bine to form compounds of solid solutions.[12] This has also been denied.[13] While I have not made any experiments myself, I feel certain that Burgess is right and that this is purely a question of chemistry. The surface between two metals is a thin weld, and it must show the same strength no matter how it has been made. In other words the adhesion of an ideally-made electrolytic deposit will approach that of a casting having the same size of crystals. Presence of grease, of air-bubbles, or of occluded mother liquor will impair the contact and weaken the joint. If the metal is deposited in a state of strain, the break will come at the weakest point. These are matters of general knowledge in making welds or castings, and they are just as much first principles in electrolytic work. No one seems to have been struck by the absurdity of the statement to be found in most books on plating that nickel cannot be plated on nickel because it will not adhere. If this were true it would not be possible to deposit more than in infinitesimally thin film of nickel electrolytically. While it requires a higher voltage to deposit nickel than copper, nickel does not precipitate copper to any appreciable extent when immersed in a copper sulphate solution. The nickel becomes passive and is probably covered with a thin film of oxide. What people mean is that an "active" nickel containing hydrogen will not adhere to a "passive" nickel. There is nothing surprising or mysterious about this.

The alleged rusting of iron, when plated with nickel in a chloride instead of a sulphate solution, if really true, is purely a chemical phenomenon and rests on the different behavior of occluded chloride and sulphate solutions. If the distinction is a real one, special experiments would soon show whether the freedom from rust in sulphate solutions is due to the iron becoming passive or to the formation of an insoluble basic salt.

The general results of this paper are:

1. A bad deposit is always due to the precipitation with the metal of some salt or non-metal.

2. Addition to the solution of anything which will dissolve this salt or non-metal will tend to prevent its precipitation and to improve the quality of the deposit.

3. Any beneficial action of a reducing agent is probably due to the removal from the solution of dissolved oxygen.

4. A fine-grained deposit is favored by high current density and potential difference, by acidity and alkalinity, by low temperature and by colloids.

5. Solutions containing oxidizing agents appear to yield small crystals, while larger crystals are obtained from solutions containing reducing agents.

6. The adherence of deposits rests on the adhesion of the two metals.

The discussion has been incomplete. The formation of the "trees" has only been touched upon and the question of "bright" deposits has not been raised. All of the generalizations rest on insufficient evidence. On the other hand, the consideration of the chemistry of electroplating has given us a working hypothesis which can be tested experimentally.

[12] Kahlenberg, Electrochemical Industry, 1, 201 (1903)
[13] Burgess, Electrochemical Industry, 1, 204 (1903)

ELECTROMETALLURGY OF IRON AND STEEL IN CANADA.

We have repeatedly referred in our columns to the great interest which is being taken in Canada in the use of the electric furnace in the iron and steel industries. Concerning the trip of a committee, appointed by the Canadian Government, to study various processes of this kind in Europe, we published notices on pages 48, 198, 280 and 329 of our present volume.

We are now informed that an electric furnace plant on a very large scale is to be erected at Ottawa, Canada, for the reduction of pig iron from iron ores in connection with the electric production and refining of steel. Thus, the electric furnace will enter into competition with the blast furnace.

DIFFERENCES IN THE ELECTROLYSIS OF POTASSIUM CHLORIDE AND SODIUM CHLORIDE.

By F. Winteler, Ph. D.

At first glance it might appear that there should be no differences between the phenomena during electrolysis of potassium chloride and sodium chloride, with the exception that on account of the higher atomic weight of potassium the same current yields in the same time more potassium hydroxide than sodium hydroxide (theoretically 2.095 grams of caustic potash, 1.496 grams caustic soda and 1.323 grams of chlorine per ampere-hour). There are, however, other differences.

In the first place, commercial common salt is never pure, while pure potassium chloride may be had in trade. Common salt contains in the average 1 per cent of magnesium chloride and 1 per cent of sulphuric acid which is bound as sulphate. For most of the other chemical purposes for which common salt is used, these impurities are unimportant, while they are of the greatest importance for the electrolytic process of making caustic soda and chlorine, as well as chlorate The content of magnesia is advantageous for chlorate manufacture, since it raises the efficiency of the process; on the other hand, it makes the use of a diaphragm cell unsuitable for the manufacture of caustic soda. The content of sulphate has the same effect.

Secondly, common salt has about the same solubility at ordinary and at higher temperatures, while potassium chloride is much more soluble at higher temperatures than at ordinary temperatures. This fact causes differences in the evaporation of the cell solutions, whereby potassium chloride must be separated from caustic potash and sodium chloride from caustic soda. The designs of the apparatus are different for the electrolysis of the two salts.

Thirdly, potassium chlorate (which is formed in the anodic compartment during the cathodic production of KOH solution in a diaphragm cell) is only slightly soluble in water at ordinary temperatures; and even at elevated temperatures its solubility in concentrated potassium chloride solution (of which the anolyte consists) is rather small. On the other hand, sodium chlorate is easily soluble in water and in concentrated sodium chloride solution. If concentrated sodium chlorate solution is added to a concentrated sodium chloride solution, the latter is precipitated, but no chlorate.

This high solubility renders the use of a diaphragm cell unsuitable for the electrolysis of sodium chloride, since chlorate would gradually accumulate in the anodic compartment; it would then take part in the electrolysis resulting in the development of oxygen and of chlorine containing carbonic acid.

On the other hand, the high solubility of sodium chlorate at elevated temperatures is utilized for separating it from common salt, which has about the same solubility at ordinary and at higher temperatures. If a concentrated solution of the mixture is cooled, pure sodium chlorate is precipitated, chloride remains in solution.

The facts briefly outlined above, may now be discussed more in detail.

Electrolytic Production of Caustic Potash.

The question whether the use of a diaphragm cell is suitable for the electrolytic production of caustic potash must certainly be answered in the affirmative.

Commercial potassium chloride is 98.5 per cent pure. The balance of 1.5 per cent is made up nearly exclusively of moisture and of some ferric oxide. The latter remains back in the solution tank or in the filter press. The filtered solution represents pure potassium chloride. The first products during electrolysis are pure chlorine at the anode and potassium hydroxide at the cathode. Then the latter begins to participate in the electrolysis and OH ions travel into the anodic compartment, forming some chlorate. Since the KCl solution is maintained concentrated in the anodic compart-

ment, the chlorate which is being formed, is at once precipitated. It falls to the bottom of the anodic compartment and cannot have any deleterious effect.

If the KCl solution would not be maintained highly concentrated in the anodic compartment, chlorate would dissolve in larger quantities; it would then participate in the electrolysis and would cause destruction of the carbon anodes as well as the liberation of greater amounts of oxygen and carbonic acid in the anodic chlorine than are found in concentrated solutions.

Electrolytic Production of Caustic Potash.

The question whether the use of a diaphragm cell is suitable for the electrolytic production of caustic soda should, in my opinion, be answered in the negative, for the following three reasons.

First, the content of magnesia in commercial common salt causes the diaphragm to be clogged. At the boundary surface of the cathodic sodium hydroxide solution and the anodic sodium chloride solution saturated with chloride—*i. e.*, in the diaphragm—magnesia is deposited. Under analogous conditions, the sodium chloride electrolysis requires, therefore, in practice, 7 volts, while 3.6 volts are sufficient for the electrolysis of potassium chloride.

Secondly, the content of sulphate in the sodium chloride solution continually increases in the anodic compartment for the reason that SO_4 ions migrate into the same from the cathodic compartment, while new quantities of sulphate are continually added by filling new sodium chloride (containing sulphate as impurity) into the cell. The consequence is that the chloride electrolysis changes gradually into a sulphate electrolysis, resulting in the destruction of the carbon anodes as well as of the diaphragm.

Thirdly, as soon as caustic soda is formed in the cathode compartment by electrolysis, hydroxyl ions migrate into the anode compartment, which, on account of the excess of chlorine present therein, results in the formation of chlorate. Since sodium chlorate is easily soluble, it remains in solution, and participates in the electrolysis. The result is that the carbon anodes are destroyed and that the chlorine contains oxygen and carbonic acid.

Differences in the Evaporation of Caustic Soda and Caustic Potash Solutions.

While the mercury cathode process and the Acker process yield at once pure caustic alkali solutions, the other electrolytic methods (diaphragm process and gravity [Glocken] process) require a separation of undecomposed chloride from the caustic alkali. As is well known, the ampere-hour efficiency would be too low if one would try to change all the chloride into hydroxide. If a mixture of caustic soda and sodium chloride is evaporated until the specific gravity is 50° Baume, all sodium chloride (except 1 per cent) is precipitated even at high temperature.

The case of potassium chloride is quite different. If a mixture of potassium chloride and potassium hydroxide is evaporated until the specific gravity is 50° Baume (one should not go further, since at 52° Baume the solution solidifies when cooled), several per cent of potassium chloride remain still dissolved at the high temperature. It is therefore not possible (as in the case with caustic soda) to provide the evaporation apparatus with a device for separating the potassium chloride from the caustic potash. In this case the mixture of precipitated potassium chloride with potassium chloride dissolved in caustic potash is passed into tanks where it is allowed to cool; this is followed by separating the precipitated crystals from the solution which now contains only 1 per cent of potassium chloride, either by filtration under pressure or vacuum or by centrifugal force.

Differences in the Electrolytic Production of Potassium Chlorate and Sodium Chlorate.

If potassium chlorate is produced by electrolysis of potassium chloride, the conditions of operation may be so chosen that it precipitates in the cell itself on account of its small solubility, or it precipitates when cooled in another tank into which the hot solution is passed. The potassium chlorate thus obtained contains small amounts of potassium chloride, and by simple recrystallization in hot water, the commercial product is obtained.

Since sodium chlorate is consideraby more soluble in sodium chloride solution, it is preferable to apply in this case another method. Even in this case it is possible to get sodium chlorate crystals on the bottom of the electrolyzing cell, if the content of chlorate is pushed beyond 850 grams per liter, with 10 per cent sodium chloride. But the ampere-hour efficiency is greatly reduced under such conditions of operation, and it is, therefore, preferable, when working on an industrial scale, to push the content of $NaClO_3$ not beyond 500 or 600 grams per liter, with 10 to 12 per cent NaCl. This solution is brought into the vacuum evaporation apparatus where it is concentrated until the specific gravity is 52° Baume. Under these conditions the main part of sodium chloride is precipitated; the solution is then passed through a hot filter and cooled. Sodium chlorate then precipitates nearly free from chloride, and it may be easily purified by washing with water.

While the content of potassium chlorate in the cell solution is insignificant, the content of sodium chlorate in the cell solution is ten times as great.

The content of magnesium in common salt becomes here again of importance. During electrolysis the cathode is covered with a crust of magnesium hydroxide, and this results (as first described by Oettel) in an increase of the ampere-hour efficiency. The reason is that less hypochlorite is reduced. This exists in the cell as an intermediate product generated in the change from chloride to chlorate.

Finally, I may call attention to the fact that additions to the solution, intended to increase the efficiency, have not the same effect in electrolyzing potassium chloride and sodium chloride. It is well known that an addition of bichromate increases the efficiency of the production of chlorate. But in practice this addition is suitable only for potassium chlorate manufacture.

In the latter case fresh salt is again and again dissolved in the old mothor liquor, and the addition of bichromate is made only once, and does not need to be renewed. It is different with sodium chlorate manufacture, where, after evaporation the mother liquors are not returned into the cells, but pass only through the short way from the evaporation apparatus to the crystallization vessels. The cells are supplied with fresh salt to which fresh bichromate would have to be added again. After completion of electrolysis and evaporation, these quantities of chromate are contained in the old mother liquors so that chromate accumulates in the same until a point is reached when the sodium chlorate crystals are no longer white, but yellow.

If bichromate is to be used in the manufacture of sodium chlorate, the chromate should be precipitated from time to time by means of barium chloride. It is, however, preferable not to use this addition at all, since the presence of sulphate from the original water of solution may lead to difficulties in connection with the filtration of the precipitates.

It will thus be seen that there are essential differences in the electrolysis on an industrial scale of potassium chloride and sodium chloride.

"Sixty-Mesh Screen."—In a recent issue of the *Engineering and Mining Journal* attention is called to the confusion existing in the literature concerning the use of the form "mesh." It is remarked that some journals use the term "3600-mesh," where universal usage in this country would apply the term 60-mesh. A 60-mesh screen contains 60 holes per linear inch, or 3600 holes per square inch. There should be absolute uniformity in the use of technical terms.

ELECTROLYSIS AND CATALYSIS*.

By Prof. W. Ostwald.

The chemical result of the conduction of an electric current through an electrolyte is made up of two very different effects, namely, the phenomena of the conduction through the electrolyte and those concerned with the *transfer of electric charges* at the electrodes. With respect to the first effect, we have clear and definite conceptions based on the universally confirmed theory of Hittorf. According to this theory, the mechanism is of the greatest simplicity, namely, the cations and anions migrate in opposite directions and with mobilities which depend mainly on the specific nature of the ions, but also on the solvent, the concentration and the temperature. The process which results in the second effect, namely, the ionic discharge or the general transfer of charges at the electrodes, also seemed at first to be simple and clear. True, the assumption that the ions which accomplish the transportation of the current through the electrolyte are also the materials which undergo the electric change at the electrodes, could not be supported; it was the recognition of the fact that both can be different, which enabled the development of the proper explanation of the phenomenon of electrolytic conduction itself. Berzelius still based his electrochemical system on such an incorrect conception of the electrolytic phenomena. He at first and chiefly tested the salts of the alkaline metals and earths; since *bases* and *acids,* besides hydrogen and oxygen, result from their electrolysis, he regarded the former two substances as the real constituents of the salts, and based his entire chemical system on this misconception derived from his experiments. Even Faraday held rather erroneous views in this regard, though we owe to him the name and conception of the ions. The first one who was consistent was Daniell, who throughout assumed the metals to be the cations of the salts. This scientist's conception of the mechanism of the transportation of electricity by the ions was still imperfect, and it was then Hittorf who worked out the theory in this respect to perfect simplicity and clearness; to him we owe the statement that electrolytes are salts, and the experimental methods for determining the nature of the ions in every given case, as also the relation of their migration velocities independently of any possible electrode reactions.

The new idea of decisive importance was that of a *secondary reaction.* While by the conduction of the current through the electrolyte a certain ion may be transferred to the cathode, it does not necessarily follow that it is there deposited or liberated. In a solution of potassium chloride it is undoubtedly the potassium ion which transports the positive electricity to the cathode. Yet it does not appear there as the product of electrolysis, but in its stead, potassium hydroxide and hydrogen are formed. This is explained by the conception that directly or primarily potassium is deposited, which, however, cannot exist in contact with the water of the solution and reacts with it, forming potassium hydroxide and hydrogen.

First of all, this view enables us to conceive the same simple mechanism for the conduction of the current through an electrolyte, in the two theoretically fully analogous cases of the electrolysis of the salts of heavy metals which do not decompose water, and the electrolysis of the salts of light metals which decompose water, although both cases are apparently quite different from an experimental point of view. Another result is that the apparent contradiction to Faraday's law is avoided, which in the case of electrolysis of salts of light metals, could be found in the fact that, besides liberation of oxygen and hydrogen, the formation of acid and alkali appear as immediate effects of the electrolysis. Finally our view gives an explanation of the fact that in some cases, instead of the secondary reactions, it is possible to get the primary products by means of a slight modification of the conditions of the experiment. For instance, in the case of the alkali metals this is possible by the use of a mercury cathode.

In the course of time, the necessity has manifested itself to consider a great many reactions as secondary. The best-known example is the decomposition of water between inert electrodes. Since water itself is a poor conductor, alkali or acid is added and in former descriptions of this method it was stated that these additions are made only for the purpose to render the water a "better conductor." Now we know with sufficient certainty that the conduction of the current is really accomplished by the ions of the additions, and, in the case of an acid, we consider the oxygen developed at the anode as the result of a secondary reaction between the discharged anion and the solvent water, while in the case of an alkali, we must assume secondary reactions even at both electrons, namely, at the cathode the reaction between alkali metal and water, and at the anode the change of the discharged hydroxyl ion into oxygen and water.

By the development of modern electrochemistry our views on these questions have been modified so as to be more precise. If at an electrode, several processes are possible by means of which the transfer of electricity from the electrolyte into the electrode may take place, we have to assume that that reaction will take place for which the potential difference is a maximum. Or, in other words, if we gradually increase the e. m. f. applied at the terminals of the cell, beginning with zero e. m. f., then, of all possible ionic discharges, those will first occur which require the smallest potential difference.

However, the potential difference for any electrode reaction has in general not a constant value, but depends upon the temperature and to a considerable degree upon the *concentration;* and the latter manifests its strongest influence exclusively at *low* concentrations. If we start from "molar" solutions and increase the concentration, we cannot go beyond ten-times molar concentrations for experimental reasons, because more concentrated solutions of electrolytes cannot be prepared in general. Within the limits mentioned, the maximum possible difference is about 0.06 volt for the electrolytic production of any constituent of these solutions, out of the concentrated or out of the dilute solution. On the other hand, if we start again with molar solutions and decrease the concentration, the same difference of e. m. f. (0.6 volt) is found for every decrease of the concentration to one-tenth its former value; hence, for 0.001 molar solution, compared with molar ones, it is already 0.17 as maximum, and for 0.000001 molar solutions it is twice as much. For infinitely dilute solution it is theoretically infinite; but experimentally one does not come beyond 2 volts.

The following important conclusion may herefrom be drawn. If there are several possibilities for the reaction at one electrode, the really occurring chemical reaction depends not only on the nature of the possible chemical reactions, but upon the concentration of the substances which are present, and by suitably varying the latter, we can bring any reaction to any point in the voltage series.

Now, it is a universal fact that the electrolytic process itself results in a decrease of the concentration of that substance in the neighborhood of the anode which is involved at that moment in the electrode reaction. Hence, any such reaction has the tendency to stop by itself and to be replaced by that reaction which can and will take place as the next one with increasing voltage. Moreover, since the voltage is influenced only by the concentration *at the electrode itself,* not by the average concentration in the whole electrolyte, this "polarization" would necessarily take place almost instantaneously after the current has begun to flow, if there were not other processes which bring the exhausted kind of ion again in sufficient quantity to the electrode.

These compensating influences are of a two-fold kind. First we have diffusion which tends to make good any decrease of concentration with a force proportional to the existing con-

* A paper presented at the International Electrical Congress.

centration difference. Secondly, we may have chemical reactions which are caused by the exhaustion of the electrolytically changed ions, since the quilibrium which had been disturbed by their disappearance begins to restitute itself, and therefore also tends to counteract the loss. Both compensating processes start, however, only after the loss had been established, and are therefore never able to reproduce the original condition. The result is always a polarization, *i. e.*, an e. m. f. which counteracts the applied e. m. f.[1]

The value of the e. m. f. of polarization depends evidently upon the final decrease of concentration of the electrolytically changed ion. For this purpose we have to consider the stationary condition which is reached after the first variable processes have terminated. For the case that the compensation for the exhausted ions is accomplished by diffusion only, Helmholtz has already given the principles of what takes place. This may be briefly summarized as follows:

The current causes a consumption of the active ion at the electrode surface, the quantity consumed being proportional to the quantity of electricity which has passed. But the electrolytic migration of the ions does not bring as many new ions to the cathode as are consumed, but only a certain portion of this number, this portion being given by the ratio of the migration velocity of the active ion to the sum of the migration velocities of both ions. Hence, there must necessarily result ionic exhaustion which is counteracted by diffusion. The exhaustion progresses so far until diffusion—which has simultaneously increases on account of the increasing concentration difference—brings exactly the missing amount of ions in form of its salt to the electrode. There will be produced, therefore, finally, a certain distinct concentration difference between the electrode surface and the main part of the solution, and there will be a corresponding distinct e. m. f. of polarization. Since the diffusing quantity of salt is proportional to the coefficient of diffusion and to the *difference* of concentration, while the e. m. f. of polarization is proportional to the *ratio* of the concentrations, it follows that with the same current density the e. m. f. of polarization must become the greater, the smaller the total concentration of the active ion.

These considerations hold good directly for primary electrolysis in which the current is transported by the same ion which undergoes the change of concentration at the electrode. For secondary electrolysis we have only to consider what the influence o fthe current will be, according to Faraday's law, upon the concentration of the electrolytic ion at the electrode. Let us consider, for instance, the case of "water decomposition," and let us distinguish the two cases in which, for increasing the conductivity, an acid or a base is added. With an acid solution we have to consider at the cathode the concentration of the hydrogen ion and we have primary electrolysis At the anode we had to consider first the concentration of the anion, for instance, the SO_4 ion. By its reaction with water, oxygen and sulphuric acid is formed according to the equation,

$$SO_4 + H_2O = H_2SO_4 + O$$

i. e., this process yields sulphuric acid which disintegrates again into its ions. The concentrations of the SO_4 ion is therefore not diminished, but increased, and this increase corresponds exactly to the decrease of the concentration at the cathode. Diffusion will now carry the sulphuric acid from the anode away, and this will lead to a stationary condition. The total result is not a compensation of the two e. m. f's. of polarization at the electrodes, but since an *increase* of concentration has a smaller influence on the potential than an equal *decrease*, in the whole we will have a polarization in the ordinary sense, *i. e.*, the passage of the current is rendered more difficult and this will be the case to a greater extent the higher the current density and the smaller the total concentration.

[1] There are known a few cases of abnormal polarization in which the current causes an e. m. f. of polarization of the same direction as the applied e. m. f.; their theoretical explanation is possible on the basis of theory given in the following:

If a caustic potash solution is electrolyzed, we have a similar increase of the potassium hydroxide concentration at the cathode, due to the ionic migration, since it is not removed there from the solution, and we thus have here quite similar conditions as exist for sulphuric acid near the anode. At the anode we have in the case of caustic potash electrolysis, the reaction, $2OH = H_2O + O$. The concentration of the HO is approximately equal to that of the potassium, but the latter decreases on account of the migration of the ions. Further, immediately at the anode a layer of pure water is formed. The total result in this case is again a polarization in the ordinary sense.

All these considerations are based, however, upon the further supposition that *the chemical reactions by which the secondary products are formed, occur with a speed infinitely great in comparison with the other processes.* This is a supposition which, while very approximately fulfilled in the cases which we have considered, yet is not necessarily fulfilled in all cases. If we have to do with reaction velocities which are not infinitely great, there arise a great many new questions which we did not need to answer so far.

It may be asked, for instance, whether at the anode in a potassium hydroxide solution the secondary reaction $2OH = H_2O + O$, or even $4OH = 2H_2O + O_2$ occurs, or whether we have rather a primary reaction, namely, the discharge of bivalent oxygen ions. True, the existence of such an ion O'' has not yet been proven; it can never exist in considerable quantities, because it reacts soon with water according to the equation,

$$O'' + H_2O = 2OH'$$

and forms hydroxyl ions. On the other hand, one may state that it must always be present in very small quantities wherever hydroyl ions are present, since the above reaction also takes place in the reverse direction, as read from the right to the left hand of the equation, and the simultaneous concentrations of the two kinds of ions are determined by the (unknown) equilibrium constant of this reversible reaction. As long as this reaction also takes place with a speed which is infinitely large compared with that of the electrolytic processes, it does not matter which reaction is assumed, since no measurable quantity is thereby influenced; it is therefore not possible to decide which of the different possible reactions really occurs, and a discussion on this point does not fulfill any useful purpose.

Let us now imagine the possibility of rendering the reaction between hydroxyl ions and bivalent oxygen ions infinitely slow by some means. It would then be possible to decide which of the two reactions occurs at the electrode (under the supposition that it is either the one or the other). If it is the hydroxyl ion which is discharged, the decrease of concentration, produced by a given current, will have a relatively much smaller effect than an equivalent decrease of concentration of the oxygen ion which is present in a much smaller concentration. Under equal conditions we would, therefore, get a small polarization in the first case, and a very strong polarization in the second case; and by measurements of the polarization we could decide which of the two reactions really takes place.

Such means of changing the speed of a given reaction within very wide limits, exist really in chemistry in what is called *catalyzers.* Herefrom it is at once evident which very esential and important part the catalyzers are able to play in electrolytic action. By retarding one of the possible reactions by means of a negative or retarding catalyzer, we are able to *exclude* its influence from the electrolytic process. By accelerating by means of a catalyzer a reaction which is of itself slow, we can *include* it into the electrolytic process. In other words, we are no longer compelled to let the current act in the way stated by the above simple law, but in principle, we are now able, *by applying suitable catalyzers, to prescribe to the current that reaction which we want to take place*, and it does

not matter at which point of the voltage series this reaction is situated.

This fundamental idea may be applied in two directions. First, in *synthetic* work; if we suppress by negative catalyzers those reactions which would take place before the desired one, we can bring the desired reaction to the front, or, if the reactions which take place before the desired one, occur with a low speed, we can accelerate the speed of the desired reaction by means of a positive catalyzer, and can thus produce the same effect. The second application is *for analyzing the reactions which really take place at the electrodes.* If these reactions are essentially influenced by a certain addition, and if we know the single reaction which is altered catalytically by the addition, we can conclude that this reaction takes an essential part in the electrode process. If a catalyzer of known specific activity does not influence the electrode reactions, we can draw the reverse conclusion and state that that reaction is not a part of the electrode process.

In connection with this, it should be emphasized that what is called above briefly *"the electrode process,"* is in reality a rather complex phenomenon. In the simplest case—for instance, in the primary electrolysis of a silver salt—this reaction consists in the change of the silver ion to metallic silver. But "metallic silver" is not a well-defined substance, since we know elementary silver in very different allotropic states. Here the very general rule manifests itself that a system, when changing from one state to another one, first assumes the unstable intermediate states which change step by step into more stable ones; in the case of explosive antimony, detected by Gore, it is well known that one of these states remains metastable for a longer time. One may say, therefore, that the first product in the cathodic deposition of silver is that which is formed as the next step from the silver ion after the loss of its positive charge—*i. e.*, silver dissolved in water, probably of the molecular weight Ag. On account of the presence of white metallic silver the silver cannot continue to exist in this state, but changes into the stable form of white silver. At the cathode a distinct proportion of dissolved silver ions to dissolved silver metal will therefore be established, and this proportion will determine the potential by means of an equation similar to that given by Peters[2] for the potential of a mixture of ferrous and ferric salts. The greater the speed of the charge of dissolved silver into the white solid metal, the smaller will be the concentration of the dissolved silver metal and the more it will approximate that which is given by the self-solubility of white silver[3], and which therefore represents the equilibrium potential of a silver electrode.

Similar considerations hold good for the secondary reactions at an electrode. Thus, as primary anodic product of the electrolysis of dilute sulphuric acid a substance SO_4 may be assumed which reacts with the solvent water with any (probably very high) speed, to form oxygen and sulphuric acid. In the case of concentrated sulphuric acid which contains mainly the ion HSO_4', not the substance HSO_4, but its polymerisation product, $H_2S_2O_8$ is obtained, or its ions, as conceivable primary product. If, however, the anode has too strong catalytic properties, for instance, if it consists of a large platinum plate, the persulphuric acid which is formed soon disintegrates into sulphuric acid and oxygen, and the unstable intermediate product does not remain.

It will thus be seen that even the simplest electrode reactions are made up of a plurality of reactions following each other step by step. Since each of the same can be influenced catalytically, it is already evident that a very great variety of results is possible. We should further consider that many of the unstable substances, which, during electrolysis are formed as intermediate products and which quickly disappear, are not yet known separately with respect to their properties, and especially with respect to the action of catalyzers upon the same. Under these circumstances it will be evident what an abundance of peculiar and unexpected phenomena we may hope to detect in this way, and how much new knowledge we may expect to obtain from a systematic investigation of this field. The literature of electrochemistry already contains a great number of separate facts which are not only understood more easily, but applied with greater safety, if considered from the points of view given in this paper. I regret I cannot go into details; I only wish to remark that for some time Prof. Luther, with his scholars, has attacked this problem from different sides; the papers already published by them, and even more the still unpublished investigations, will show the generalty and variety with which this scientist has understood to develop this principle and to render it useful.

[2] Zeit. f. Phys. Chemie, v. 26, p. 200, 1898.

[3] Such a solubility must be assumed in any case. This follows from general reasons and from the facts, detected by Naegeli, of the storing poison action, the "oligodynamics" of water in contact with metallic silver.

THE MANUFACTURE OF FERRO-ALLOYS IN THE ELECTRIC FURNACE.

By George P. Scholl, Ph. D.

(*Continued from page* 351.)

A third process of manufacturing the alloy consists in using an impure carbon containing a high percentage of silica for the manufacture of calcium carbide and adding iron to the charge. The alloy is thus obtained at the same time as the carbide. Jouve (loc. cit.) maintains that such procedure gives very impure products on account of the formation of alkaline earth silicides which remain in the carbide as well as in the alloy. The alkaline earth silicides are stated to retain with great facility the impurities, such as phosphorous, sulphur, arsenic, which exists in the carbons used and especially in the impure material, which is always rich in pyrites. Alloys manufactured by this process were exhibited at the Paris exposition in 1900. It may suffice here to briefly mention a method proposed by Gin, which is described in Electrochemical Industry, Vol. 2, page 149, and which consists essentially in the formation of an alkaline or alkaline earth silicate in one electric furnace and the reduction of the silicate in a second electric furnace after it has been mixed with the requisite quantities of oxide of iron or metallic iron and carbon. Alkaline or alkaline earth oxides are thus obtained in connection with the ferro-alloy. He states that in order to obtain ferro-silicon with about 20 per cent of silicon, the mixture is made up according to the formula $BaSiO_3 + Fe_2O_3 + 5\ C = Fe_2Si + BaO + 5\ CO$, or with metallic iron $BaSiO_3 + 2\ Fe + 2\ C = Fe_2Si + BaO + 2\ CO$. The operation is stated to be carried out with a current of between 25 and 35 volts, the expenditure of energy being between 50 and 60 watts per square centimeter section of the electrode. The barium silicate has previously been obtained by treating a mixture of barium sulphate, broken quartz or non-clayey sand and charcoal in another electric furnace.

The method proposed by Tone, described and illustrated in Electrochemical Industry, Vol. 2, page 111, though primarily intended for the production of metallic silicon, may also be mentioned here.

Albert Keller, in his paper before the Iron and Steel Institute mentioned above, gives some particulars as to the manufacture of ferro-silicon according to his process at Livet, France. He states that its manufacture can only be carried out with real economy in a large installation and with powerful electric furnaces. Those in use at Livet are of 650 hp. each, and they are of the resistance type, presumably similar to the one described above. The raw materials employed are preferably quartz, scrap iron and coke. Quartz is more suitable than sand, inasmuch as the latter often occasions obstructions in the furnace. Scrap iron and steel are preferred to iron ore, for the reason that, working with a pure quartz, the work proceeds without the formation of any appreciable amount of slag. The purity of the product obtained is almost exclusively dependent upon the care taken in manufacturing.

Keller states that the energy acquired to manufacture 1 ton of ferro-silicon containing 30 per cent of silicon, amounts to 3500 kw.-hours. A works disposing of 10,000 effective horse-power on the turbine shaft could, therefore, produce 16,000 tons of ferro-silicon annually, or about 50 tons per day. Power of 4000 hp. is devoted in Livet to the manufacture of ferro-silicon. Analysis of the 50 per cent alloy manufactured by Keller, are given as containing phosphorus 0.02 per cent, sulphur a trace and carbon a trace.

Some data relative to the manufacture of ferro-silicon by the Willson Aluminium Company, at Kanawha Falls, W. Va., are given by Dr. Haber in the *Zeitscrift f. Electrochemie,* Vol. 9, page 363, in the course of a report on the electrochemical industries in this country. He states that the manufacture of the alloy is carried out with iron ore, river sand and coke, the two latter being obtained quite cheaply. A cheap supply of scrap iron is not available. The composition of the iron ore is: Fe 62.34 per cent, SiO_2 7.93 per cent, P 0.4 per cent, MgO 0.09 per cent, CaO 0.72 per cent and S a trace. An average sample of the product showed the following composition: Si 28.11, Fe 69,02, Cr 2.27, S 0.04 Mn trace, P trace, C 0.54. The chromium content is accidental, being due to the manufacture of ferro-chromium in the same furnace. The expenditure of energy for the production of one kilogram of silicon in the product is given as 26½ hp. hours, which is equivalent to $26.5 \times 300 = 7950$ hp. hours for the 30 per cent alloy per ton, or 5930 kw. hours.

Gin, in a paper in L'Eclairage Electrique, Vol. 27, May 4, 1900, details a number of experiments undertaken by him on the manufacture of ferro-silicon. He worked with hammer scale, quartz and coke, with siliceous iron ores, quartzy sand and coke, and with slag from the acid Martin furnace and coke. When using hammer scale, quartz and coke, he obtained 200 grams per kw. hour, of an alloy of the following composition: Si 21.45, Fe 77.50, undetermined 1.05. This is equivalent to an energy expenditure of 5000 kw per ton of alloy. For this he calculates the cost per ton as follows: electric energy, 31 francs (a rate of about 50 francs per kw. year of 365 days); labor, 15 francs; hammer scale, 36 francs; quartz, 9 francs; coke, 29 francs; electrodes, 24 francs; maintenance and repairs, 13 francs; amortisation, 20 francs; divers general costs, 23 francs, making a total of 200 francs (about $40) for the 20 per cent material. Undoubtedly the cost is less now than that amount.

When working with siliceous iron ores of the composition Fe_2O_3 59.2 per cent, MnO 2.1 per cent, SiO_2 24.6 per cent, water of combination and moisture 14.7 per cent, undetermined 9.4 per cent, a sand of 93.7 per cent, SiO_2, undetermined 2.1 per cent, moisture 4.2 per cent and a coke of 78.9 per cent of carbon, 11.3 per cent of ash and 9.8 per cent of moisture, in the following proportion: iron ore, 1800 kilograms; quartz sand, 420 kilograms and coke, 720 kilograms, he obtained a consumption of energy of 6200 kw. hours per ton of a product containing about 47 per cent of Si, the yield for the latter being 80 per cent.

Trials with acid Martin slag, which contained 50.42 per cent of Si_2, 2.26 per cent Al_2O_3, 34.10 per cent FeO, 9.92 per cent MnO, and 3.30 per cent of CaO, MgO, etc., with a mixture of 1680 kilos of slag and 600 kilos of coke, with 80 per cent of carbon, resulted in an expenditure of 5380 kw. per ton of a product containing Si 29.64, Fe 53.70, Mn 13.18, carbon 0.52, undetermined 2.96. The average current was 6950 amperes at 29.1 volts.

The difference in the amount of energy required per ton of ferro-silicon is easily explained when it is borne in mind that the expenditure of energy increases with the amount of silicon contained in the product obtained. The great discrepancies in the figure given by Keller, namely, 3500 kw. hours, and for Wilson, viz., 5930 kw. hours for an alloy of approximately the same silicon contents, is brought about by the former's employment of metallic iron, while the latter uses iron ore. A simple thermochemical calculation of the heat units required for the reduction of the silicon in the two cases will show that the efficiency of the furnace is not much different in the two cases.

The following calculation will give an approximate idea of the difference in heat units required for the production of one ton of 30 per cent ferro-silicon, when manufactured from metallic iron, silica and carbon, and from iron ore, silica and carbon. The following values are assumed: 1 kg. Fe for reduction from Fe_2O_3, requires 1796 cal., 1 kg. Si from SiO_2 requires 7830 cal., 1 kg. C burning to CO develops 2473 cal., spec. heat of Fe from 0° to 1400° C. average = .20, spec. heat of SiO_2 = .25, spec. heat of carbon = .50. It is assumed, for simplicity's sake, that the reduction takes place exclusively according to the formula $SiO_2 + 2C = Si + 2CO$, and that the materials used are chemically pure. It is, of course, not difficult to make a similar calculation for the impure materials as they are actually used in practice. Under the conditions assumed the theoretical heat units required for a ton of 30 per cent alloy will be as follows:

Heating up 700 kgs. Fe to 1400° C. = $700 \times .20 \times 1400 = 196{,}000$ cal. Heating up 643 kgs. Si to 1400° C. = $643 \times .25 \times 1400 = 225{,}050$ cal. Heating up 257 kgs. C to 1400° C. = $257 \times .50 \times 1400 = 179{,}900$ cal. For reduction of 300 kgs. Si from SiO_2 $300 \times 7830 = 2{,}349{,}900$ cal. A total of 2,950,850 cal. Heat gained by burning of 257 kgs. C to CO = $257 \times 2473 = 635{,}561$ cal. Total heat required = 2,315,289 cal., which is about 2730 kw.-hours. Comparing this with the figure of 3500 kw.-hours, mentioned above as given by Keller as actually obtained in practice, and taking into consideration the unavoidable losses of heat in practice and the heat required for various purposes owing to the impure materials dealt with, which have not been considered in the above calculation, it is apparent, that the efficiency of his furnace is quite satisfactory.

When the calculation is made for the production of an alloy of the same percentage from oxide of iron, silica and carbon, assuming also in this case the materials to be chemically pure, the heat requirements are as follows:

Heating up of 1000 kgs. Fe_2O_3 to 1400° C. = $1000 \times .19 \times 1400 = 266{,}000$ cal. Heating up of 643 kgs. SiO_2 to 1400° C. = $643 \times .25 \times 1400 = 225{,}050$ cal. Heating up of $225 + 257 = 582$ kgs. C to 1400° C. = $582 \times .50 \times 1400 = 407{,}400$ cal. Reducing 700 kgs. Fe from $Fe_2O_3 = 700 \times 1796 = 1{,}257{,}200$ cal. Reducing 300 kgs. Si from $SiO_2 = 300 \times 7830 = 2{,}349{,}900$ cal. Total, 4,505,550 cal. Heat gained by burning of 582 kgs. C to CO = $582 \times 2473 = 1{,}439{,}286$ cal. Total heat required = 3,066,264 cal. This amounts to about 3565 kw.-hours. The figure actually obtained by Wilson, as given by Dr. Haber (l. c.), in the manufacture of a 25 to 30 per cent alloy, is 5930 kw.-hours. Considering the greater metallurgical complexity of the ore process as compared with the smelting of iron borings, and the additional heat requirements for driving out moisture, and for various reactions, no account of which has been taken in the above calculation, this figure is also quite satisfactory for practical purposes.

(*To be concluded.*)

AMERICAN ELECTROCHEMICAL SOCIETY.

At the meeting of the Board of Directors, held on Sept. 2, the following gentlemen were elected members of the Society: F. E. Schmitt, New York City; James G. Marshall, Niagara Falls, N. Y.; Timothy C. Root, Buffalo, N. Y.

At the October meeting the names of the following gentlemen will come up for election: Elliott M. Sergeant, Boonton, N. J.; E. P. Schock, Austin, Texas; Martin L. Griffin, Mechanicsville, N. Y.; E. S. Wittnebel, New York City; F. E. Schuetz, New York City.

The spring meeting, 1905, of the Society will be held in Boston, invitations having been extended by representatives of Harvard University, and of the Massachusetts Institute.

ELECTROCHEMISTRY AT THE INTERNATIONAL ELECTRICAL CONGRESS OF ST. LOUIS.

The fifth International Congress met at St. Louis on the morning of September 12 in the Music Hall of the Colesium. While the acceptances of membership were over 2000, the number of members who attended the Congress personally was about 715.

The inaugural general meeting was called to order by Prof. Elihu Thomson, who introduced Hon. D. R. Francis, president of the World's Fair, who welcomed the Congress to St. Louis. He expressed the opinion that it would be a long time, in this country at least, before another universal exposition would be attempted, but that there will probably be international expositions in special lines, and he believes that electricity is the one field in which there is likely to be another international exposition before a great many more years. He paid a tribute to the excellence of the electrical part of the St. Louis Fair, which is under the direction of Prof. W. E. Goldsborough.

Prof. Elihu Thomson, in his address outlined the organization of the Congress and complimented the general secretary Dr. A. E. Kennelly, and the treasurer, Mr. W. D. Weaver, on the excellent and very effective work they had done. The Congress then proceeded to effect its regular organization and speeches were held by foreign delegates. After the conclusion of the general meeting the Congress then revolved itself into its constituents' eight sections, as follows:

Section A.—General Theory—Mathematical, Experimental. Chairman, Prof. E. L. Nichols; Secretary, Prof. H. T. Barnes.

Section B.—General Applications. Chairman, Prof. C. P. Steinmetz; Secretary, Prof. Samuel Sheldon.

Section C.—Electrochemistry. Chairman, Prof. H. S. Carhart; Secretary, Mr. Carl Hering.

Section D.—Electric Power Transmission. Chairman, Mr. Charles F. Scott; Secretary, Dr. Louis Bell.

Section E.—Electric Light and Distribution. Chairman, J. W. Lieb, Jr.; Secretary, Mr. Gano S. Dunn.

Section F.—Electric Transportation. Chairman, Dr. Louis Duncan; Secretary, Mr. A. H. Armstrong.

Section G.—Electric Communication. Chairman, Mr. F. W. Jones; Secretary, Mr. B. Gherardi.

Section H.—Electrotherapeutics. Chairman, Dr. W. J. Morton; Secretary, Mr. W. J. Jenks.

In the following we give a full report of Section C (Electrochemistry). The programme of this section had been arranged with the effective co-operation of the American Electrochemical Society and the two meetings on Tuesday and Thursday were joint meetings of Section C and of the Electrochemical Society, while on Friday an independent meeting of the American Electrochemical Society was held which had no official connection with the Congress. In the following report, however, the meetings of Section C and of the American Electrochemical Society are reported together.

Report of Meeting of Section C (Electrochemistry) and of the American Electrochemical Society.

Monday Session.

Immediately after the inaugural general meeting of the Congress had been closed, section C, devoted to electrochemistry, assembled, with Prof. Hy. S. Carhart as chairman and Mr. Carl Hering as secretary. On account of the limited time at disposal, only one paper was presented at the Monday session.

The Relation of the Hypothesis of Compressible Atoms to Electrochemistry.

A paper on this subject was presented by Prof. Theodore William Richards, of Harvard University. In the absence of the author it was read by Prof. G. W. Patterson. The idea had occurred to the author that since affinity binds chemical elements firmly together in compounds, it should also exert pressure, and should therefore tend to combat all the influences existent in matter tending to distend the substance. The mutual affinity of two elements in a compound should, therefore, tend to diminish the volume of this compound; and, other things being equal, the greater the affinity, the greater would be the change of volume and the smaller would be the final volume of the resulting compound. If this relation really held true, it should be most clearly perceptible in compressible substances; hence, a number of compounds of the easily compressible halogens, chlorine, bromine and iodine, were studied with regard to this possible relationship. It was discovered that, in general, the volume of a solid chloride or bromide was much less than the sum of the volumes of the metal and the liquid chlorine or bromine entering into its composition; and, moreover, the more energetic the reaction, the greater was the change in volume during its progress. That is to say, a great affinity evidently causes a great contraction.

The relation, although in some cases quite striking, is in other cases concealed by other circumstances, especially by the differences in compressibility of various substances. It has recently been shown that, as one would expect, the more compressible the element, the greater the contraction which occurs for a given expenditure of energy. The demonstration of this additional fact is a strong evidence that affinity really exerts pressure, and that the volume of a liquid or solid is dependent upon the intensity of this pressure. The attraction of cohesion also was shown to exert a similar effect. When corrected for the compressibility of the factors in a reaction, and for the cohesion of both factors and products, the correspondence between the output of chemical energy and the change of volume during the reaction becomes so close as to leave little doubt as to the fundamental nature of the relation. In any attempt to penetrate further into the reason of these facts, some assumption avowedly hypothetical, must be made concerning the ultimate nature of material. For the present purpose the atomic hypothesis furnishes the most convenient foundation.

The further question now presents itself: What is that which is compressed by this pressure? In other words, what is the distending tendency in solids or liquids? Does the pressure of affinity simply restrict the vibrations of separate hard particles in an empty space, or is the atom itself compressible? The author thinks that the former usually accepted hypothesis does not sufficiently explain the difference between a solid and a gas.

The purpose of the paper of Prof. Richards is to show that the hypothesis of compressible atoms, dealing, as it does, with very intimate relations of energy and material, is not without suggestiveness to the electrochemist, and hence also to the electrical engineer.

In the first place, one may ask: How would a compressible atom behave on leaving an electrode and going into solution as an ion? It would then be attacked by an entirely new set of affinities, being in its new position surrounded by molecules of the solvent, instead of by atoms similar to itself, and these new affinities exerting new intensity of pressure would be expected to change its volume. Moreover, the solvent, being itself in part exposed to new internal pressures, would also change in volume. As a matter of fact, a marked change of volume is always observed when a positive and negative element go into solution in the ionized conditon. The author quotes the examples of potassic chloride, sodium chloride and potassic bromide. Among these similar compounds, and in many other cases, it usually appears that the greater the

electrical potential afforded by the double ionizaton, the greater the change of volume; also, the greater the compressibility of the elements concerned, the greater the change in volume. These changes of volume on ionization also seem to be approximately parallel with the changes of volume on forming the corresponding hydroxides; just as the heats of ionization are approximately parallel with the heats of formation of the hydroxides. This parallelism may indicate that the effective agency causing ionization or galvanic solution of a metal is the attraction of the metal for the oxygen or the hydrogen of water—most probably the oxygen. Although these regularities are fairly prominent on comparing the properties of similar elements in a natural group, exceptions are not hard to find on comparing very dissimilar substances. At least, a part of these exceptions may be traced to the expected simultaneous contraction of the solvent. That the solvent really often contracts is manifest from the fact that in some cases (notably the hydroxides of lithium, sodium, and barium, and the sulphates of zinc, cobalt, nickel and magnesium) the solution occupies less space than the water alone, from which it is made. In this connection the author calls attention to the well-known fact that during the formation of eighteen grams of water from its ions in the neutralization of a strong acid by a strong base, an increase of volume of 20 milliliters occurs—an increase greater than the volume of the water formed.

Another less direct relation of the theory of compressible atoms to electrochemistry is to be found in the effect of change of volume of reacting systems upon their specific heat. Thomsen pointed out long ago that a contraction in a reaction between aqueous solutions is usually accompanied by a loss of heat-capacity of the reacting system; and it is possible to cite many other cases in which is is true. Probably, however, the cause of this loss is not so much the decrease in volume, as the irregular stress caused by tthe simultaneous presence of very different affinities. In terms of the hypothesis of compressible atoms—atomic distortion seems to cause a diminution of heat capacity. As a kinetic conception. this interpretation is plausible.

The relation of this change of heat capacity to electrochemistry is very important. Recent study has made it appear highly probable that a change in heat capacity during a reaction is the chief, if not the only, reason why the total-energy change (or the heat of reaction) is not equal to the electrical work which the reaction performs in a galvanic cell. In colloquial language, the heat energy which is displaced, or forced out, by a diminution of heat-capacity, does not seem to be able to perform work. If this be true, change of heat capacity is responsible for the "bound energy" of a galvanic cell, and, therefore, according to Helmholtz's equation, for its change of potential with the temperature. If, further, the preceding conclusion based upon the theory of compressible atoms be also accepted, the fundamental cause of this temperature coefficient of the electromotive force is referred back to atomic compression and distortion, which diminish the possibility of heat-vibration in the compressible atom.

The author then gives an explanation of Faraday's law on the basis of the theory of compressible atoms. To the electrochemist who has nothing to do with electrical capacity, the quantity-dimension of electricity is important merely as a number. He recognizes it only because it is proportional to equivalent weight of deposited metal, or to equivalent volume of evolved gas. Still more simply, it may be said to represent to him nothing but the number of atomic contacts which are made or broken in a given reaction. Therefore, the electrochemist, attempting to discover the relation of the compressible atom to galvanic deposition, naturally first seeks to imagine what would happen to a compressible atom on making or breaking a firmly united atomic contact with another atom.

Evidently, for each union with other atoms, a given atom would give and suffer a shock of impact or combination. The exact effect of this shock upon the atom itself cannot be determined; but if the atom is compressible throughout, many forms of vibration or temporary rhythmical distortion might be possible because of this shock. One of the most probable forms is, perhaps, a vortex motion; and it will be seen that this form lends itself best to further interpretation. If the atom were perfectly elastic, such a vortex would continue to exist indefinitely, when once formed.

We may imagine, then, that each collision of atomic combination starts or transfers a vortex or some other form of self-perpetuating shock. Then the deposition of a given number of chemical equivalents will result in the transfer of a given number of shocks, or a given quantity of electricity, and Faraday's law is explained. In short, in order to conceive logically of this law, one need not ascribe weight or mass to the electron—a permanent vortex will represent the needed unit as well as a ponderable particle. But only a compressible atom could hold or carry such an infinitesimal vortex, hence this hypothesis is dependent upon the hypothesis of compressible atoms.

This easy explanation of Faraday's law without a material conception of electricity leads one to inquire whether or not other relations of electricity might not likewise be satisfied by a vortical conception of the unit of electrical quantity. A complete study of the details of this possible explanation would be out of place, but a few of the electrical properties of substance may be mentioned in this connection. For example, the electrical conductivity of solids is in many cases what it would be expected to be, if their atoms were compressible. Atomic distortion would be expected to interfere with the ready transference of the vortices. The simpler the crystalline form, the less distorted would be the individual atoms, and the more easily would the vortices be received and transmitted from one atom to another. On the other hand, with irregular atoms, permanently distorted by chemical affinity, the uneven structure would receive and transmit the vortices less easily, and the potential energy of the mutual repulsion would be converted into heat. As a matter of fact, the two best electrical conductors among metals, silver and copper, crystallize in the regular system, and the poorest solid conductors among pure metals, bismuth, antimony and arsenic, are of less symmetrical crystalline structure. The non-metals which are all poor conductors, are still more noticeably complex in symmetry.

The relatively slight conductivity of alloys and compounds points in the same direction; for heterogeneity of atomic structure would imply irregular internal pressures, great atomic distortion, and hence, poor conductivity. The considerable effect on conductivity of even slight impurity in a metal and the extremely low conductivity of substances like glass and cellulose are well known, and accord with this interpretation.

Again, it is easy to see how increased thermal energy, which, if atoms are compressible, must be supposed to exist as a simpler oscillation of a portion of the atomic centers, would interfere with the reception and transmission of this new vortex-motion, and hence to see why the conductivity of solids should decrease on raising the temperature. Moreover, one would expect the slightly distorted atoms, easily receiving the electrical vortex, should usually likewise transmit more rapidly the simpler oscillations of heat energy, which is a fact.

The explanation of the brilliant experiments of J. J. Thomson and his pupils on the basis of the vortical electron is possible, if one admits, as Thomson is quite willing to do, the existence of electrical inertia independent of gravitational effect. In this case, the cathode ray is to be considered as a collection of disembodied vortices, which may only be driven through the wave-bearing medium under the stress of great difference of potential. Another alternative must be adopted if one doubts the somewhat complicated evidence concerning the relative masses of the cathode-corpuscle and the atom,

and believes the two to be identical. In this case it is necessary to imagine that a single atom can receive many vortices under the peculiar circumstances attending the cathode discharge; *i. e.*, that it is polyatomic.

The author does not claim that the hypothesis of compressible atoms represents truly the actual fact; indeed, atoms, in any shape, are an imaginary conception which may not have any counterpart in reality. "It has been claimed by a few that any hypothesis is harmful, but some of the most brilliant of scientific workers have used them as a continual inspiration. Faraday, one of the greatest of pioneers, dreamed thousands of such scientific day-dreams. To him, these were nothing but a benefit; for, although led on by visions, he knew well the difference between substance and shadow. He never confounded hypothesis with fact; and when new facts overthrew a favorite imagination, he would discard the latter gladly, rejoicing that it had led him to the discovery of the new truth."

The discussion of the paper was very brief. Prof. H. S. Carhart made a remark with respect to Richards' application of his hypothesis to the Gibbs-Helmholtz equation; he thinks that this hypothesis would only explain those cases of galvanic cells in which the temperature coefficient of e. m. f. is negative; *i. e.*, when heat is given off to the outside during an isothermic discharge. Prof. Patterson remarked that the other case would also be explained, if actual expansion would be observed.

Tuesday Session.

The session on Tuesday was a joint meeting of Section C of the International Electrical Congress and of the American Electrochemical Society.

Electrical Extraction of Nitrogen from the Air.

A paper on this subject was presented by Mr. J. Sigfrid Edstrom. The author points out that the demand for Chile saltpeter is increasing and the consumption growing heavier every year in spite of the rapidly rising prices. It is chiefly used for manufacturing nitric acid and fertilizers. In the year 1901 the consumption of Chile saltpeter in Germany

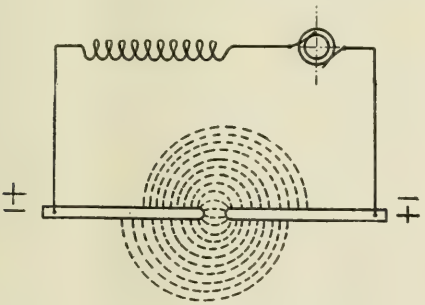


FIG. 1.—FIXATION OF ATMOSPHERIC NITROGEN.

alone was 500,000 tons. Of this quantity 75 per cent were used for fertilizers, 20 per cent for the manufacture of nitric acid, 3 per cent for the manufacture of nitrate of potash, and 2 per cent for the manufacture of sulphuric acid. The saltpeter mines in Chile are not inexhaustible; on the basis of statistical data the author estimates that they will be exhausted somewhere about 1940.

Under these circumstances it is not to be wondered that in several ways other means of producing compounds of nitrogen have been sought. The nitrogen which is contained in the air has been the source which has most naturally been turned to in seeking to produce a commercially useful article. The Siemens & Halske Co., of Berlin, investigated a method invented by Dr. Frank for manufacturing cyanamide of calcium ($CaCN_2$). Originally carbide of calcium was heated and treated by a current of nitrogen. The nitrogen was obtained by carrying a current of air over glowing copper. The copper unites with the oxygen of the air and the nitrogen remains. Later, the same results were obtained by carrying the nitrogen over a heated mixture of chalk and carbon in the same proportion as used in making calcium-carbide. The cyanamide of calcium has been tried as a fertilizer with good results. The method of Frank is as yet, however, only in its experimental state.

Most of the experiments for the manufacture of compounds of nitrogen are, however, based on a compound with oxygen. The author gives a review of the work of Priestley and Cavendish, Bradley and Lovejoy, de Kowalski and Moscicki, and describes then at length the process of C. Birkeland and S. Eyde, of Christiana. Prof. Birkeland and Mr. Eyde based their arrangements on the well-known fact that the electric current in the arc and with it the arc itself, can be deflected by a magnetic field, the deflection being at right angle to the lines of force.

If the horizontal electrodes are connected to a generator in series with a suitable inductance coil, and a strong magnetic field is applied near the electrodes in horizontal direction and at a right angle to the direction of the electrodes, the arc between the electrodes will momentarily be carried upward or downward. It will then be broken, while simultaneously a new straight arc is formed between the electrodes, which is again carried outwards, etc. The speed of the formation, motion and breaking of the arcs is so rapid that the arc can

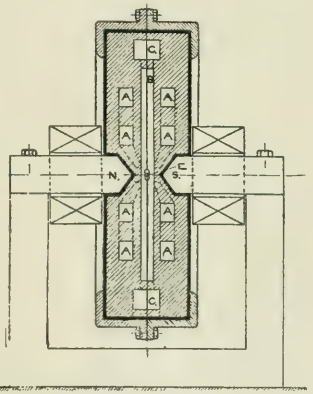


FIG. 2.—FIXATION OF ATMOSPHERIC NITROGEN.

be formed several thousand times a second. In the practical form of the ovens only some hundred arcs per second are used.

If the magnetic field is excited by a direct current, and the generator delivers direct current for the arc, a continual series of arcs will be formed, moving radially with a speed corresponding to the strength of the magnetic field. The striking points of the arc along the surface of the electrodes are also moving away from the points at the same speed. Thus the phenomena appear to the eye like a disc of arcs with the shape of almost a complete semi-circle. The movement of the arc near the electrodes is usually more rapid at the negative than at the positive electrodes, shifting the center of the circular disc somewhat to one side of a line joining the electrodes. If the magnetic field is excited by alternating current, and the arc is fed by direct current, the arcs will vibrate between opposite sides of the electrodes. This will also be the case if the arc is fed by alternating current and the magnetic field by direct current, in which case the phenomena will appear as indicated in Fig. 1. It is principally this arrangement which has been used by the inventors.

Fig. 2 shows the electric oven complete in a vertical section at right angles to the electrodes. The air that is to pass the oven is forced through the channels *A* and from there into the arc-chambers of the oven *B*, around and in the neighborhood of the electrodes *E*. Having passed this space from the center, and coming into the most intimate contact with the disc of arcs, the air passes out into the channel *C*, and leaves the oven mixed with a certain percentage of oxidized nitrogen.

The chief differences between this apparatus and that of former inventors are pointed out as follows by the author. While, with Bradley and Lovejoy and de Kowalski's methods, the energy in every arc must be lowered to the least possible in order to obtain an economical system, the method of Birkeland offers no objection to employing large amounts of energy in the disc of arcs. On the other hand, experiments have proved that the economical efficiency increases with the amount of energy employed at the electrodes.

One of the ovens, which is still in operation, has consumed from 75 to 200 kilowatts in the disc of arcs between one single pair of electrodes, and lately an oven with a disc of arcs for 500 kilowatts has been built. The 200-kw. oven has been fed with alternating current of 50 cycles frequency and 5000 volts pressure.

In spite of the relatively large current, the electrodes in Birkeland's oven have up to the present been used without interruption for several hundred hours. Owing to the fact that the striking points of the arc move along the electrodes, the destructive influence of the arc is inconsiderable. The electrodes can, for this reason, be made of very cheap material, such as copper or iron, and of such dimensions that they can easily be cooled by means of air or water, keeping their temperature within reasonable limits.

In the oven of Birkeland and Eyde, which was built about a year and a half ago, a small amount of energy was used in the disc of arcs, only seven to ten kilowatts. The efficiency of this apparatus was at first only 400 kilograms HNO_3 per kilowatt and year. The next ovens were constructed for an increased consumption of energy and have now, through continual improvements reached an efficiency of 900 kilograms HNO_3 per kilowatt and year. The energy referred to is the amount of energy in the disc of arcs itself. Some of the factors that have been considered in connection with the improvement of the oven are: The degree of moisture in the impressed air, its temperature, its amount of oxygen, the amount of air impressed per kw.-hour, the different strengths of electric current used, the voltage of the electric current, the frequency, the ovens arranged in series and parallel electrically, as well as with regard to the impressed gases, the strength of the magnetic field, the insulation of the oven to prevent the loss of heat, the introduction of various contact substances.

The air coming from the oven contains about 2 or 3 per cent of nitric oxide (NO). In order to be utilized it must be transformed into nitrogen peroxide (NO_2). This is done in a reaction tank of thin sheet iron enamelled on its inner side. From the reaction tank the gases go through an exhauster of clay, where they come into contact with drips of thin nitric acid. From here the gases pass on through the absorption system, consisting of four towers for water and one tower for a solution of caustic soda. In each tower the fluid is sent through the tower several times. The strongest acid runs always through tower No. 1, where the gases first pass, the next strongest through tower No. 2, and the weakest through tower No. 4. When the desired concentration is reached in tower No. 1 the acid is removed. The acid from tower No. 2 is then put into No. 1, from tower No. 3 into No. 2, and No. 4 into No. 3. Through tower No. 4 new water is passed. The process thus works according to the counter-current principle. The alakli tower contains, as previously noted, a solution of caustic soda. The gases from No. 4 pass through this tower. The remainder of the gases is absorbed here, and a mixture of nitrate and nitrite of soda is formed. From this pure nitrite of soda is manufactured. The acid taken from tower No. 1 is either concentrated by use of Valentiner apparatus and shipped, or is turned into nitrate of calcium or nitrate of potassium. The process is said to have been put into actual operation, compounds of nitrogen being manufactured.

In the discussion which followed Prof. C. F. Burgess pointed out that the figure of the output given by the author, namely, 900 kg. HNO_3 per kw.-year, indicates a pretty high efficiency, if HNO_3 means 100 per cent acid. Mr. Edstrom confirmed this, but called attention to the fact that 900 kg. is the output per kw.-year, the electrical energy being that consumed in the arc itself; the total power consumption is therefore greater. Moreover, power is not by any means the only item of expense. Dr. E. F. Roeber remarked that if the arc is fed with direct current and for the magnetic field which deviates the arc, a revolving field is used (such as applied in the primary of an induction motor), the arcs will cover a globe rather than a disc, and would, therefore, act on a greater quantity of air; it might thus be possible to get a still higher efficiency. Mr. Edstrom replied that he did not know that experiments in this direction had been made.

The Chemistry of Electroplating.

A paper on this subject was then presented by Prof. Wilder D. Bancroft, of Cornell University. It is printed in full on another page of this issue. The paper elicited an animated and interesting discussion, which was opened by Dr. E. F. Kern, who read a long communication by Mr. A. G. Betts.

Mr. Betts believes that some of Prof. Bancroft's generalizations are based on insufficient or untrustworthy experimental evidence. He states especially that he has repeated all experiments in the articles of Glaser on lead deposition, and has been entirely unable to verify this author's results; he therefore concludes that no theories should be based on them. He also objects to Prof. Bancroft's statement that a fine-grained deposit is favored by high-current density, and says he found that it is favored rather by a low-current density.

Mr. Betts considers that there are two main causes for the failure of an electric deposit. Either it may fail from being slimy, grading off into being soft, unsound and weak. He believes that this is due to the co-deposition of foreign conducting particles, in general caused by the presence in the solution of a small quantity of some metal of less chemical affinity than the metal being deposited. The foreign metal is precipitated in the minutest particles all over the surface, and if it comes down in too large quantity, or its affinity for the main metal is so weak that it is not immediately absorbed into an alloy, the same phenomenon takes place on an atomic scale which takes place, on a visual scale, when, for example, copper is being deposited and particles of slime are floating in the electrolyte. A particle of anode slime attaches itself to the cathode and very soon causes the formation of an insecurely attached lump of solid metal. The lumps are usually very easily knocked off, and a particle of slime is almost invariably found underneath. A slimy metal must consist of such lumps on an infinitesimal scale.

The other cause of failure considered by Mr. Betts is the growth of a deposit toward the anode; the more elevated a particular point is from the cathode surface, the more rapid its growth. There are then formed differences of concentration, in fact we can here apply the theory of concentration cells.

In depositing antimony from a solution of antimony trichloride, in which ferric chloride was continually introduced in small quantities, Betts obtained a deposit that was as smooth and shiny as glass. In this case the ferric chloride in the solution performed the function of continually cutting off projections as fast as started. By the time the iron salt had reached an incipient cavity, it had passed and already

reacted with the antimony of a neighboring projection, so that the rate of reaction was less, the less the particular point was in the current of solution. The amount of ferric chloride used was from 1-10 to 1-5 the amount necessary to redissolve all the antimony deposited.

In depositing silver from a nitrate solution, the deposit consists of more or less loose crystals, and projections are formed. From a cyanide solution the deposit is clean and solid. Mr. Betts thinks the reason is that with the cyanide solution the e. m. f. of the minute concentration cells that must exist at the cathode is much smaller than with the nitrate solution.

In the dissolution of an anode the conditions are exactly reverse to those at the cathode. A solution which will give projections at the cathode, ought for the same reason to give pits in the anode. In the dissolution of a lead anode in a fluosilicate solution, Mr. Betts has noticed that with gelatine present, the surface of the lead underneath the anode slime remains much smoother than in the absence of gelatine. This fact would seem to prove that the cause of projections at a cathode is not to be sought in the chemical composition of the deposit, but in the physics of the solution.

The next speaker was Dr. Louis Kahlenberg, who emphasized that the chemical make-up of a solution is the vital factor; compared with this, current density, potential, temperature, etc., are only of secondary importance. He thinks that Bancroft has made an excellent beginning, and every electroplater should give this matter his careful attention. Concerning the formation of an alloy at the boundary surface of cathode and deposit, he said that from Roberts-Austen's experiments it is sure that there is really a diffusion of one metal into the other, an alloying.

Dr. E. F. Kern said that to get a smooth deposit, it is necessary that no impurities should be introduced mechanically into the deposit. He referred to his and Betts' experiments with the lead voltameter (see the paper below).

Prof. C. F. Burgess said that electroplating, while the oldest electrochemical industry, is still in bad shape. One often does not get the same results as former experimenters; this is often due to the fact that the descriptions of experiments do not give all details. Concerning Betts' statement that the particles of impurity appear to attract the current, he thinks there is rather a treeing around the same. He thinks that everybody who has worked in this field will remember instances which, in one point or another, appear to contradict some of Bancroft's generalizations.

Prof. Bancroft, in his reply, wished such discrepancies would be pointed out to him, so that they could be tested. He showed that some criticisms of his paper were based on misunderstandings. He concluded that the object of his paper is to state concisely some general principles which can be tested experimentally, and which thus can be shown conclusively to be either right or wrong.

The Carbon Cell.

A paper on this subject, by Prof. F. Haber and Dr. L Bruner, of the Institute of Technology, of Carlsruhe, Germany, was then read, in the absence of the authors, by Prof. Burgess. The object of the paper is to give an explanation of the action of the Jacques cell, which consists of carbon, fused sodium hydrate, iron; and the explanation offered by the authors is that it acts as an oxygen-hydrogen gas cell.

The iron electrode in the fused sodium hydrate is gradually covered with a protecting layer or skin of oxide. As soon as this has been produced, the iron is no longer attacked, while previously it went into solution in the fused salt as iron oxide, with the development of hydrogen gas. This protecting skin can be produced rapidly if the iron is dipped for a short time into fused saltpeter, and subsequently, carefully freed from the saltpeter by means of water. The iron thus coated with this protecting skin, is called "passive," because the fused sodium hydrate produces no further changes on it.

This passive iron represents an oxygen electrode on which the atmosphere oxygen acts similarly, but better, than on a platinized platinum electrode dipped into an aqueous conducting solution. This action of the oxygen is brought about by the presence of sodium manganate, which is always present in small quantities in fused commercial sodium hydrate, and especially when in contact with commercial iron, and its presence can easily be proved chemically.

The passive iron, as an unattackable electrode, can be replaced by another inert electrode, for instance by platinum, and without changing the force and the method of action of the electrode in fused sodium hydrate containing manganese.

If platinum is placed into pure sodium hydrate the potential at the electrode is uncertain. A very small quantity of a manganate suffices to give rise to a different value, which does not change during a further addition of a manganate up to 2 per cent of the weight of the sodium hydrate.

If the added sodium manganate is reduced by forcing in some hydrogen or carbon monoxide, or by the addition of sodium oxalate or sodium formate, quite an extraordinary change will take place in the potential. But by forcing in some atmospheric oxygen the original value of the potential is again reached.

"In these experiments the potential of the platinum electrode is thus brought about by the absorption of oxygen. If a permanganate is added to fused sodium hydrate, oxygen will be evolved and the potential will, contrary to the other case, be brought about by the evolution of oxygen. These potentials are measured most simply by letting the syphon of a decinormal-electrode terminate in a small vessel containing concentrated sodium hydrate, which is in electric contact with the fused salt which is to be tested, by means of a rod of solid sodium hydrate. In all the measurements the fused salt was in a large silver crucible. The observed values are collected in the following table for different temperatures. The temperature was measured thermoelectrically.

Centigrade degrees, 312, 336, 360, 388, 412, 472, 532.

Potential in volts against decinormal-electrode, —0.265, 0.294, —0.314, —0.333, —0.353, —0.431, —0.472.

These values were measured with a platinum electrode, a small quantity of the manganate being added to the sodium hydrate. Numerous tests showed that absolutely equal values of the potential are obtained with an electrode of passive iron."

On the other hand, when a carbon electrode is tested in the way above described for iron and platinum, all possible values can be observed between —0.6 and —1.5 volts toward the decinormal-electrode. With closer study one finds that the potential approaches the value —1.5 volts more and more, the more rapidly the carbon is attacked in the fused sodium hydrate with the evolution of gas. Ordinary arc light carbons can generally be made to produce a free gas evolution when the fused salt in which it is dipped is heated to above 500° C. They then reach quite or nearly the value —1.5 volts and remain at this value when the fused salt in which they are dipped is cooled to the point of solidification. But as the accompanying evolution of gas gradually diminishes at a lower temperature (about 350°), the potential will simultaneously change; it will diminish to the values —1.3 or —1.2 volts, etc. The gas which the carbon electrode evolves in the hot fused sodium hydrate is hydrogen gas.

If, instead of the carbon electrode, a platinum tube is dipped into the fused sodium hydrate, and pure hydrogen gas is led through it into the liquid, one obtains with a strong current of gas the potential —1.5 volts, and this will be the case at all temperatures between 500° and the point of solidification of the fused salt. The potential of the carbon in the fused sodium hydrate is, according to this, not determined directly by the carbon, but by the hydrogen which the action of the carbon on the fused salt sets free. The temperature produces no effect on the potential within the given wide range, but the rapidity of the evolution of the hydrogen is of great importance.

The authors state that thermoelectric phenomena take no part in the production of these electromotive actions. For these forces do not depend in the least on the materials iron and carbon, but only on the gases oxygen and hydrogen, and the same platinum tube shows alternately the force of the iron and the carbon electrode, if at constant temperature we pass through it oxygen and hydrogen respectively.

The Jacques cell is without importance from the practical standpoint, because during its action the valuable carbon electrode and the equally expensive sodium hydrate are changed into cheap soda, only to obtain a little hydrogen which acts electromotively. From the theoretical standpoint such a hydrogen-oxygen chain offers very much of importance. It is differentiated from the old well-known Grove hydrogen-oxygen chain, in that it is not liquid water, but a solution of water in fused sodium hydrate, which is produced by its action. The paper is concluded by a brief account of some theoretical calculations.

The discussion was opened by Prof. Burgess, who read a longer communication of Mr. C. J. Reed. Mr. Reed thinks that the authors have not given sufficient experimental evidence of their conclusions. He does not believe that there is a continual layer of iron oxide, nor does he find any explanation in the paper of the effect attributed to manganate. He remarks that the theory of the authors does not explain the fact that a current of illuminating gas passed through the cell has the same effect as air. Mr. Reed believes that Ostwald's assumption is correct that the chemical reaction is oxidation of carbon and reduction of iron oxide. If this is so, this reaction gives no e. m. f. Hence, we cannot escape the conclusion that the action of the cell is essentially thermoelectric in the sense that the electrical energy supplied by the cell has its origin in the heat supplied to the cell from the outside.

Prof. Bancroft and Prof. Kahlenberg also made two brief remarks on the paper.

The Electrochemical Series of Metals.

A paper on this subject was presented by Prof. Louis Kahlenberg, of the University of Wisconsin.

The current conception of the electrochemical series of the metals is the arrangement of the latter in a series, so that any metal will be electropositive to all that follow it, and electronegative to all that precede it; and that any member of the series will chemically replace all the metals that follow it, and in turn be replaced by those that precede it in the series. In seeking combinations of metals that would produce the highest electromotive forces, Volta discovered the possibility of arranging metals in an electrochemical series; though, as pointed out by Ostwald in his history of electrochemistry, he did not at first realize that he had thus discovered a fundamental property of the metals.

Since the time of Volta the electrochemical series of the metals has figured with more or less prominence in all treatises on chemistry and electrochemistry, and the general feeling with regard to the electrochemical series at present is that it really represents a fundamental property of the metals, and that, though the character of the electrolyte into which the metals are dipped when the electromotive forces are measured, affects the electrochemical series somewhat, such effects are but slight, and the order of the metals in the series remains essentially the same in all cases. The author thinks that Nernst's theory of solution tension has strengthened this view, but points out that experiments have shown the electrolytic solution tension of a metal to vary with the nature of the solvent.

Prof. Kahlenberg gives a review of the extended researches which have been carried out in his laboratory. The outcome of all this work is the establishment of the fact that at a fixed temperature the difference of potential between a metal and an electrolyte depends upon the character of the metal and upon the composition of the electrolyte. Not only does the character of the solvent affect this difference of potential, or, if the theory of Nernst and the theory of electrolytic dissociation be assumed, not only does the osmotic pressure of the simple ions of the metal in the solution and the so-called electrolytic solution tension of the metal determine the difference of potential, but *every* ingredient used in making up the solution affects this difference of potential to some extent, and frequently very materially indeed.

Nor would the assumption of so-called complex ions, or of an influence which the solutes might have on the concentration of the ions of the metal in question (for which assumptions there would moreover frequently be no grounds) enable one to escape from the conclusion that the electrolyte solution tension of a metal is influenced not only by the solvent, but also by the solute. But if the electrolytic solution tension of a metal is determined by the character of the solvent, and also by that of the solute, it is plainly evident that this quantity, which—according to the author—is viewed by Nernst as an inherent property of the metal itself, is in reality as much a function of all the ingredients in the electrolyte as of the metal. In this connection it is of fundamental importance to bear in mind that the change which the difference of potential between a metal and the surrounding solution undergoes when any constituent of the solution is altered, is in general different, either as to magnitude or direction, or both, for different metals toward the same solution.

The facts established experimentally point to the conclusion that the difference of potential between a metal and an electrolyte into which the metal dips is due to the mutual chemical interaction of electrode and electrolyte. The author states that on the basis of this view the facts at hand can readily be explained. It becomes clear at once why a change on any ingredients of the electrolyte should affect the e. m. f. developed, and why in the case of different metals this effect should be different as to magnitude or sign, or both, for one and the same change in the electrolyte.

At first thought it might seem that this view of ascribing the e. m. f. developed at the junction between a metal and an electrolyte to the chemical affinity, or strain tending toward interaction, existing between the metal and the electrolyte, would not enable one to detect regularities existing in the phenomena of the electromotive forces that have actually been measured, but this is a delusion. Similar metals behave similarly in the development of potential differences toward an electrolyte, and similar ingredients introduced into an electrolyte produce similar effects toward one and the same metal in the development of potential differences. Bearing this in mind, enables one to detect much of regularity in the electromotive force measured. The author gives several striking instances of how the difference of potential between a metal and an electrolyte changes when one of the ingredients of the electrolyte is gradually altered, and deals at some length with the results obtained in his laboratory by Mr. J. P. Magnusson in measurements of the differences of potential between various metals dropping in a one-tenth normal solution of lithium chloride, while the solvent was a mixture of pyridine and water in various proportions. The results are summarized in Fig. 3, where the abscissæ represent the percentage of water in the solvent (mixture of water and pyridine). In each case the chain measured was of the form metal, $-\frac{n}{10}$ LiCl in pyridine, $\frac{n}{10}$ water, or pyridine + water, $-\frac{n}{10}$ $AgNO_3$ in pyridine, Ag. The second half of the chain always remained unchanged; and for the value of this half of the combination the author had previously found — 0.573 volt, on the assumption that the half cell — nKCl.HgCl|Hg is equal to — 0.56 volt. The ordinates in Fig. 3 represent the difference of potential of the first half of the combination above referred to (*i. e.*, the e. m. f. of the metal against the solution of LiCl) referred to the value — 0.56 volt for the normal calomel electrode

In the discussion which followed Prof. W. D. Bancroft remarked that Kahlenberg's results throw doubt on the correctness of some suppositions made in the thermodynamical proof of some principles of physical chemistry on which our methods of determining molecular weights are based; it seems quite certain that a semi-permeable membrane has an affinity for the liquid passing through. Dr. Patten gave an outline of the directions in which these investigations of Dr. Kahlenberg and his scholars might be extended in future. He also pointed out that measurements of potentials of aluminium

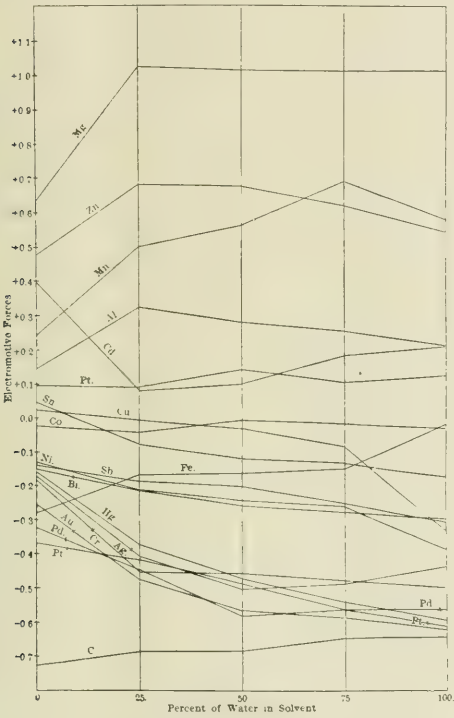


FIG. 3.—EFFECT ON E. M. F. OF VARYING PERCENTAGES OF SOLVENT IN WATER.

are generally unreliable, if not special precautions are taken. Dr. Kahlenberg agreed that the question of potentials of aluminium is quite a debatable one.

The Lead Voltameter

A paper on this subject, by Mr. Anson G. Betts and Dr. Edward F. Kern, was then read by Dr. Kern. The object of the paper is to describe the lead voltameter and to show wherein it possesses features which might be a means of its replacing the copper voltameter for technical purposes, such as calibrating electrical instruments and for comparison of the ampere-hour efficiency of electrochemical porcesses.

Previous to the Betts process of refining lead alloys, the crystalline non-adherent deposit which forms on the cathode in the ordinary solutions was not suited for voltametric measurements. One of the claims of the Betts patent is the formation of a smooth, dense, coherent, solid deposit of lead on the cathode in an acid solution of lead fluosilicate, which contains an organic reducing agent, such as gelatine, glue or pyrogallol, etc. It is an inexpensive solution, easily prepared, and easily maintained; it conducts the current well, is non-volatile, and is stable under electrolysis, which properties make it a suitable electrolyte for a voltameter. It also possesses the property that under ordinary conditions, when a soluble anode is used, no lead peroxide is formed, because the electrical potential required is so low, being in the proximity of 0.18 volt for concentrated solutions, and about 0.40 volt for very dilute solutions, when using a current density of 10 to 15 amperes per square foot.

The lead electrolyte was prepared by treating ordinary white quartz with commercial hydrofluoric acid (30 per cent acid) forming a solution of hydro-fluo-silicic acid (H_2SiF_6). Heating the solution of hydrofluoric acid caused more rapid solution of the quartz. White lead (basic lead carbonate) was added to the solution in the required quantity. It dissolved rapidly and completely with effervescence, and any hydrofluoric acid which did not react with the silica formed an insoluble precipitate of lead fluoride, which was filtered off. Lead fluosilicate is a very soluble salt. It dissolves in about 28 per cent of its weight of water at 20° C. The crystalline salt has the composition $PbSiF_6.4H_2O$.

The solution was diluted so as to contain 17 grams of $PbSiF_6$ and 7 grams of free H_2SiF_6 in 100 c. c. solution. After adding 1 gram of gelatine (dissolved in hot water) to 2000 c. c. solution, the electrolyte was rendered absolutely pure, in respect to metals which can deposit with lead, by electrolyzing for several days, using electrodes of refined lead. The anodes were wrapped with two thicknesses of clean linen, so as to prevent the impurities from dropping off and floating in the electrolyte. The small amount of soluble impurities in the electrolyte was due principally to the impurities in the white lead used for making the solution. The electrolysis was continued for four days at temperatures between 17° C. and 57° C., using a current density at the electrodes of 10 to 12 amperes per square foot. A small amount of "anode sludge" remained behind and in order to prevent it from being oxidized by the atmosphere and subsequently going into solution, melted vaseline was poured on the surface of the electrolyte. The deposit which formed on the cathode was smooth, dense and non-crystalline.

After purifying the electrolyte, about 800 grams of absolutely pure lead was made by electrolysis, using ordinary refined lead, wrapped with clean linen, for the anodes. The refined lead which was deposited on the cathode was further refined by reversing the current and redepositing it on new cathodes. The solution was protected from the atmosphere by a covering of melted vaseline. The purified lead was melted, cast into a thin plate and then rolled into sheets about 1/32 inch to 1/16 inch thick. The sheets were cut into strips of suitable size and used as anodes for the lead voltameter. No residue was left on dissolving the purified anodes by electrolysis.

The lead electrolyte used for the first series of experiments contained 13.5 per cent of lead fluo-silicate ($PbSiF_6$) and 6.5 per cent of free hydro-fluo-silicic acid (H_2SiF_6). It was prepared by diluting the purified electrolyte and then precipitating the excess of lead by pure sulphuric acid. The anodes were strips of the purified lead. Two glass beakers, each containing 500 cubic cms. of the electrolyte, served as voltameters. (The action of the electrolyte on glass is small and the solution in a short time loses its originally small solvent action on glass. It may be kept in glass bottles.) The two lead voltameters were connected in series with the silver voltameter, and for convenience of approximately determining the current, an ammeter was also placed in the circuit. Later on, experiments were also made with a solution containing 8.5 per cent $PbSiF_6$ and 2.5 per cent free H_2SiF_6.

The authors give details of an exact test of the lead voltameter, in comparison with the silver voltameter. In most experiments two anodes and one cathode were used; this arrangement was found to be the most satisfactory. The cathode was suspended between the two anodes and below the surface of the electrolyte by means of a thin narrow strip of metal or wire, so as to prevent the action of the atmosphere

on the lead at the surface of the electrolyte. This action may also be retarded by using an electrolyte which is less acid than that used in the experiments. Even with an almost neutral solution of lead fluo-silicate its conductivity would be sufficiently high for a voltameter.

The lead deposit, unlike the silver deposit, is smooth, dense, coherent and non-crystalline. It has a density equal to that of cast lead, so that there is no danger of losing by washing, drying and weighing. The deposit, which forms even with high-current densities (20 to 25 amperes per square foot) of cathode exposure in a fairly strong electrolyte is perfectly smooth, dense and non-crystalline, so long as the electrolyte contains about one part gelatine by weight in two to four thousand parts of solution. With age and by use, the gelatine slowly loses its reducing property. The appearance of the deposit indicates when more gelatine is needed, so that as long as the deposit forms smooth and non-crystalline none need be added. The gelatine is added by dissolving a small quantity in hot water, and adding it directly to the electrolyte. The moment it is added the crystallization of the lead is prevented.

The current density used within fairly great limits in the lead voltameter does not effect the results. In one experiment a current density of 37 amperes per square foot was employed, and the results obtained agreed as closely with the silver voltameter as when lower current densities were used. The limit of the current density seems to be controlled by the strength of the electrolyte and by its circulation. The more dilute the solution the less is the limit of current density which can be used.

The lead voltameter is well adapted for obtaining electrochemical efficiencies of experiments which require long duration. Lead has the property in common with copper in that the deposit, which forms in some electrolytes, is perfectly smooth, dense and non-crystalline. It, however, possesses some advantage over copper in that the electrochemical equivalent of lead is over three times as great as that of copper.

Of great importance is the fact that while an acid copper sulphate solution in contact with copper electrodes contains varying quantities of cuprous sulphate, lead exists in the solutions only as divalent ion. On this circumstance is founded the belief of the authors that the lead voltameter, properly used, will be found of extreme accuracy.

One advantage of lead over silver is its cheapness, so that with a small outlay a lead voltameter of any size may be constructed.

From an electrochemical point of view the lead voltameter also has an advantage over the silver voltameter in that lead stands very high in the e. m. f. series, so that the impurities which are ordinarily contained in refined lead will remain as "sludge" on the anode, whereas the purest silver is required for the construction of a silver voltameter. The results obtained by the authors show that the lead voltameter compares very favorably with the silver voltameter, as the results are within sufficient limit of accuracy for most voltametric work. In the majority of the measurements the electroequivalent weights of the lead are almost theoretical.

Differences in the amounts of lead dissolved from the anodes and deposited on the cathodes show that oxidation of lead took place to a serious extent, particularly when the solution had not had lead electrodes recently immersed in it. For accurate work the authors recommend passing a current of pure carbon dioxide through the oxygen-free electrolyte in a covered receptacle. It is also said to be desirable to use fresh polished cathodes of lead or copper each time, rather than redeposit metal on cathodes which have already been used.

The paper was not discussed.

Chlorine in Metallurgy.

A paper on this subject was presented by Mr. James Swinburne. In the absence of the author, it was read by Mr. S. S. Sadtler. Mr. Swinburne gave a brief outline of his process of treating complex sulphide ores by means of chlorine, so as to change all sulphides into chlorides, then replacing all other metals by zinc and electrolyzing the fused zinc chloride. The process has already been described at length on pages 412 and 413 of our vol. I. (August, 1903), so that the reader may be referred to this description. In his Congress paper Mr. Swinburne evidently intended to give various illustrations of his apparatus, but they were not exhibited at the meeting.

Some historical notes given by Mr. Swinburne on the process are interesting. The first patents were in 1897, and the process was tried in the laboratory and everything worked well. It was then tried on a pound scale and worked. A works was taken in Milton and large scale experiments on electrolysis of zinc chloride and handling of chlorine were carried out. A 3000-ampere electrolytic vat was run continuously for three months. Facilities were wanting there. Mr. A. J. Smith, the general manager of the Castner-Kellner Company, saw a chance of a future in the process, and the company made arrangements to put down an experimental place next door to their works. This was done and the transforming of the sulphides into chlorides was proved on a large scale. It has been claimed that the chlorine reaction does not take place, and that fused zinc chloride cannot be electrolyzed. In fact people have proved it with test tubes. The Castner-Kellner Company, however, were able to investigate the working of the process, and to inspect the transformer consuming at the rate of 30 tons a week. They were well enough satisfied with the results to arrange to take the works over, acquiring a license to make chloride of zinc. They thus use the whole process except the electrolysis, as they have a supply of chlorine from the soda works. They will run a 10,000-ampere vat for demonstration, but otherwise they will sell every metal but zinc, the zinc being sold as chloride. The only difference in the process is that zinc chloride must be much more highly refined for the market than for electrolysis, as a trace of manganese, for example, would spoil the color, but would do no harm in electrolysis. The chlorine is also damp, and has to be dried before being pumped. The Castner-Kellner Company are reorganizing the works, and reconstructing it in many details, and will probably have the first unit, dealing with 30 tons of ore a week, running this fall.

The author finally remarks that a good deal of work has been done recently on the treatment of ores with little metal content, such as copper ores running under 3 per cent, and copper, nickel and cobalt ores. These modifications have only been tried on a small scale, and so it is too soon to speak yet, but apparently low grade copper, and nickel, cobalt and, of course, their mixtures, and copper zinc ores of low content will prove amenable. Such interesting puzzles as the treatment of speiss from copper smelting works, and the smelting of antimony gold ores, have already yielded satisfactory solutions on the small scale, and fahlerz of various compositions is likely to be amenable to simple and profitable treatment.

The paper was briefly discussed. Prof. Bancroft, with reference to the notice in the paper of the Castner-Kellner Company using the process, said that electrolytic alkali plants have difficulties in using their chlorine to good commercial advantage. Mr. S. S. Sadtler remarked that while the process looks very simple on paper, yet there should be numerous great difficulties in its operation in practice.

Aluminothermics.

A special meeting of Section C of the Congress was held in the Library Hall of the Administration Building in the World's Fair on Tuesday night. Dr. Hans Goldschmidt, of Essen-Ruhr, Germany, lectured on aluminothermics. He was introduced to the audience by Dr. L. Kahlenberg. In the course of his lecture Dr. Goldschmidt made a great number of highly interesting and very effective experiments. The greater part of the lecture dealt with the uses of thermit for repairing castings and for welding rails and tubes, and with

the production of pure metals, free from carbon, by means of reduction of their oxides with aluminium. Since these subjects have already been discussed at length in our columns (especially in the two articles of Dr. Goldschmidt in our issues of November, 1903, and April, 1904), we will notice in this abstract only those points of Dr. Goldschmidt's lecture which deal with more recent developments of aluminothermics.

While speaking of the manufacture and the uses of pure metals and alloys, free from carbon, Dr. Goldschmidt remarks that ferrotitanium is being used regularly since a few years ago by several steel works. In a very peculiar way this ferrotitanium is introduced into liquid cast iron in the ladle, by means of the so-called box reaction. (See Electrochemical Industry, vol. I., p. 533.) In this way highly heated ferrotitanium is separated out at the bottom of the ladle, which alloys in statu nascendi with the content of liquid iron. The reaction taking place in the midst of the bath, the latter is more thoroughly stirred or poled than is possible by other means. Through the introduction of a small quantity of titanium, which binds the nitrogen, the composition of the bath undergoes a chemical improvement. Impurities, such as slag and others, are driven up, and the bath is further purified.

It is remarkable that the sulphur contents are appreciably reduced. The lecturer mentioned two analyses:

Cast Iron	Before Ti. addition.	After Ti. Addition.
No. I.	Mn. 0.36	Mn. 0.30
	S. 0.19	S. 0.09
	Ti	Traces.
No. II.	Mn. 0.66	Mn. 0.64
	S. 0.09	S. 0.07
	Ti.	Traces.

Of late the contents of the boxes are pressed into solid moulds, preventing the possibility of their getting unmixed and producing a perfectly regular reaction. The iron becomes considerably more fluid and it can therefore be cast at a lower temperature and will show very much less tendency to form shrink cavities. The process has been introduced in the course of the last year in a number of foundries, in particular for cylinder castings, high pressure valves, etc.

Dr. Goldschmidt then spoke of the use of "anti-piping thermit" and dealt with the use of the "box reaction" in the introduction of thermit into the risers. Formerly a small can of suitable shape was built into the bottom of the risers. Then it was considered simpler to insert the box at the end of a rod, into the liquid iron as it rose. Now in a number of works, the thermit is simply wrapped in paper and thrown on the rising liquid metal. This process is equally applied in iron and steel casting practice. For cast iron the wrapper should contain, at the bottom, a pinch of ignition powder, as the temperature of liquid cast iron is not sufficient to start the ignition of thermit. Liquid steel does not require ignition powder. Many faulty castings may be avoided by this method.

Dr. Goldschmidt then spoke of the uses of his corundum slag, obtained in every aluminothermic reaction. This artificial corundum, so-called "corubin," is very different from, and its properties are more valuable, than those of the natural product. The cause is the chemical composition of the two materials. The natural contains various impurities, such as oxide of iron, silica—even small quantities of water in chemical combination. On the other hand, the aluminogenetic corundum is nearly free from all these, and in particular absolutely free from water. This is no doubt the cause of its greater hardness compared to the natural. In consequence corubin is used for emery wheels.

A most curious and remarkable application has been made by Dr. Buchner, of Mannheim. He found that this material had an exceedinly low elastic coefficient and does not lose this property when mixed with a fire-clay binder. In this way he managed to produce vessels for chemical purposes of entirely different properties than the earthenware vessels in use up to the present. A porcelain or earthen vessel cracks very easily when exposed to even small changes of temperature. Those made of corubin behave differently. They can be heated to red heat and cooled suddenly with water without showing any tendency to crack. Dr. Goldschmidt demonstrated this by an experiment in which he heated a corubin vessel to red heat and then poured water into it; it did not crack.

Corubin offers, therefore, almost unlimited advantages to the chemical industry. Its highly refractory qualities have introduced it as a coating for bricks and tubes exposed to high temperatures. For these purposes only the corubin resulting from the chromium reaction is utilized, of which sufficient quantities are available, in consequence of the large consumption of pure carbonless chromium. This corubin requires a special preparation before being used. The aluminogenetic corubin has proved itself a valuable product for making crucibles for the thermit welding process. Such crucibles, made according to a certain recipe, will stand from fifty to sometimes 100 reactions.

After having dealt at length with the welding of rails and tubes, Dr. Goldschmidt spoke of the applications of thermit for the repair of broken castings. He mentioned that in the Russian-Japanese war thermit has played an important part, particularly on the Russian side. After the first attack of the Japanese on the Port Arthur fleet, orders for several tons were received from the Russian Government. These orders have continued to increase ever since. The remarkably speedy repairs of Russian ships were, according to accounts received by Dr. Goldschmidt, in many cases due to thermit welds. The Japanese have, of course, also used thermit, but as before the war it was less known there than in Russia, its possibilities have not received the same attention. Of course some practical experience is imperative before large quantities of thermit can be successfully handled. This experience is, however, not difficult to acquire. In far off countries thermit has been taken into constant use, although no experienced mechanics were available and the engineers had to teach themselves by closely observing the rules laid down in the pamphlets. It is just in such countries, where machinery is difficult to obtain, that thermit is of the greatest value. By its help, urgent spare castings can be made at once out of thermit steel; for instance, cog wheels.

For a special sort of repair, it is used in rolling mills for welding bosses on rolls. The surface on which the new boss is to be welded is brought to fusion heat by first pouring a little liquid iron on it, which is covered by a quantity of thermit. The latter is ignited and enables the liquid metal, which is then poured on it, to evenly weld to the roll.

In conclusion, Dr. Goldschmidt mentioned an entirely novel application, appertaining to a very difficult field, namely, the "culinary." In consequence of an old suggestion, the "Deutsche Munitions & Waffenfabrik," Karlsruhe, has constructed a very handy cooking and roasting stove, allowing a speedy warming of food and drink in the open air, by means of thermit, without a flame. This may be of great value in campaigning, for instance, on outpust duty where cooking may be done without divulging one's position to the enemy.

To avoid misunderstanding, Dr. Goldschmidt emphasized that thermit cannot be adapted to firing on a larger scale, for instance, on torpedo boats or others. In this respect it cannot compete with anthracite, as one kilo thermit gives about 450 calories, anthracite about 7000. The value of the new heat producer lies in the speed of the combustion and the concentration of the heat in a very small space, not in the great number of available calorics. For heating purposes in the ordinary sense, it can therefore only be utilized on a small scale, for very specific purposes and where, besides, a particularly low price is not of importance.

There was no session either of Section C or of the American Electrochemical Society on Wednesday.

Thursday's Meeting.

The Thursday meeting was again a joint meeting of Section C of the International Electrical Congress and of the American Electrochemical Society.

The Silver Voltameter.

The first paper of the session was presented by Dr. Karl E. Guthe, of the National Bureau of Standards, Washington D. C., on the silver voltameter. The author gave a summary of the work which has formerly been done with the silver voltameter, and which led in 1893 to the adoption of the silver voltameter as a standard for measurement of electric current by the Chicago International Electrical Congress. Though the ampere was defined as one-tenth of the unit of current of the c. g. s. system of electromagnetic units, it was added, that it "is represented sufficiently well for practical use by the unvarying current which when passed through a solution of nitrate of silver in water in accordance with standard specifications, deposits silver at the rate of 0.001118 gram per second." This value is called the electrochemical equivalent of silver.

Exact specifications as to construction and use were prepared by the National Academy of Sciences and legalized in the United States in 1894. They read as follows:

In employing the silver voltameter to measure currents of about one ampere, the following arrangements shall be adopted:

The cathode on which the silver is to be deposited shall take the form of a platinum bowl not less than 10 cms in diameter, and from 4 to 5 cms in depth.

The anode shall be a disc or plate of pure silver some 30 sq. cms in area and 2 or 3 mms in thickness.

This shall be supported horizontally in the liquid near the top of the solution by a silver rod riveted through its center. To prevent the disintegrated silver which is formed on the anode from falling upon the cathode, the anode shall be wrapped around with pure filter paper, secured at the back by suitable folding.

The liquid shall consist of a neutral solution of pure silver nitrate, containing about 15 parts by weight of the nitrate to 85 parts of water.

The resistance of the voltameter changes somewhat as the current passes. To prevent these changes having too great an effect on the current, some resistance besides that of the voltameter should be inserted in the circuit. The total metallic resistance of the circuit should not be less than 10 ohms.

Method of Making a Measurement.—The platinum bowl is to be washed consecutively with nitric acid, distilled water and absolute alcohol; it is then to be dried at 160 degs. C., and left to cool in a desiccator. When thoroughly cool it is to be weighed carefully.

It is to be nearly filled with the solution and connected to the rest of the circuit by being placed on a clean insulated copper support to which a binding screw is attached.

The anode is then to be immersed in the solution so as to be well covered by it and supported in that position; the connections to the rest of the circuit are then to be made.

Contact is to be made at the key, noting the time. The current is to be allowed to pass for not less than half an hour, and the time of breaking contact observed.

The solution is now to be removed from the bowl and the deposit washed with distilled water and left to soak for at least six hours. It is then to be rinsed successively with distilled water and absolute alcohol and dried in a hot-air bath at a temperature of about 160 degs. C. After cooling in a desiccator it is to be weighed again. The gain in mass gives the silver deposited.

To find the time average of the current in amperes, this mass, expressed in grams, must de divided by the number of seconds during which the current has passed and by 0.001118.

In determining the constant of an instrument by this method, the current should be kept as nearly uniform as possible and the readings of the instrument observed at frequent intervals of time. These observations give a curve from which the reading corresponding to the mean current (time-average of the current) can be found. The current, as calculated from the voltameter results, corresponds to this reading.

The current used in this experiment must be obtained from a battery and not from a dynamo, especially when the instrument to be calibrated is an electrodynamometer.

The author then gave a long, but concise summary of the experimental researches which have been carried out by various investigators on the reactions in and the construction of the silver voltameter. He remarks that the greatest advance in our knowledge of the subject is due to the researches of Richards and his students, who showed that the main difficulty lies in the formation of a heavy anode solution, containing a complex silver ion. The anode solution which in the ordinary type of voltameter sinks to the bottom of the vessel, producing there a star-shaped figure, will yield on electrolysis more silver than corresponds to the normal ion. Besides, this substance, formed at the anode, must be a reducing agent, since oxygen tends to eliminate it. The exact chemical constitution of the substance is not known.

The main problem is to prevent the anode solution from reaching the cathode. For this purpose Richards places the silver rod, which forms the anode, in a fine-grained porous cup and removes from time to time the solution collecting at the bottom.

Guthe fully corroborated Richards' results, but proposed a different form of the anode. The bottom of a wide porous cup is filled with granulated silver and upon this a large silver plate is pressed. In this type the rather inconvenient frequent removal of the solution was found to be unnecessary. The heavy solution is prevented by the porous cup from rapid diffusion and breaks up to a large extent when it remains in contact with silver. This secondary reaction, he believes, gives rise to the formation of the well-known dark anode slime, which is pure silver when the anode is pure.

Other arrangements may be adopted to prevent the anode solution from reaching the cathode. The latter may, for instance be suspended above the anode, or the two electrodes be placed in different vessels, connected by a siphon. From a practical point of view the latter types are, however, less convenient than the two described above.

Filter paper should not be used in the preparation of the electrolyte nor in the voltameter, since it contains organic substances which may act chemically upon the solution.

As Guthe has shown, we can distinguish two distinct types of silver voltameters, according whether the heavy anode solution reaches the cathode or not. The former to which the ordinary type and those proposed by Patterson and Guthe and by Leduc belong will on the average yield a deposit one part in 2000 larger than in the second type. Of course, for practical purposes we must select the type which will give the most concordant results. As investigations show, we can rely upon the porous cup voltameter to within one part in 20,000, even for independent series of experiments; it would, therefore, be a decided step in advance, if one of these types were substituted for the one now in common use. This would, however, necessitate a change in the accepted value of the electrochemical equivalent of silver.

The author then summarizes the results of many investigations concerning a great number of details in the construction of the voltameter and finally deals with determinations of the electrochemical equivalent of silver.

TABLE I.

Observer.	Year.	Voltameter.	Method.	Electro-chemical Equivalent	
				Found.	Corrected
				mg.	mg.
Mascart[1]	1884	Usual type.	Current balance	1.1156	1.1150
Fr. and W. Kohlrausch	1884	"	Tangent galv	1.1183	1.1177
Rayleigh and Sidgwick	1884	"	Current balance	1.1179	1.1175
Gray	1886	Plate voltameter	Sine galvan	1.1183	1.1177
Koepsel[2]	1887	Usual type	Current balance	1.1174	1.1168
Pellat and Potier[3]	1890	"	"	1.1192	1.1186
Patterson & Guthe	1898	Silveroxide type	Electrodynamometer	1.1192	1.1182
Pellat and Leduc[4]	1903	Leduc's type	Current balance	1.1195	1.1188
van Dijk & Kunst[5]	1904	Usual type	Tangent galv	1.1182	1.1176

[1] Mascart, *Journ. de Phys.*, vol. 2, p. 109, 1882 and vol. 3, p. 283, 1884.
[2] Koepsel, *Wied. Ann.*, vol. 31, p. 250, 1887.
[3] Pellat and Potier, *Journ. de Phys.*, vol. 9, p. 381, 1890.
[4] Pellat and Leduc, *C. R.*, vol. 136, p. 1649, 1903.
[5] van Dijk and Kunst, *Ann. d. Phys.*, vol. 14, p. 596, 1994, *Proc.* Kon Ak. van Wet, vol. 12, p. 141, 1904.

The electrochemical equivalent of silver has been determined repeatedly by absolute measurements, *i. e.*, by means

of instruments which allow a calculation of the current in terms of the fundamental units of mass, length and time. Among the earlier investigations only those of Rayleigh and Mrs. Sidgwick, and of Fr. and W. Kohlrausch can be considered accurate. In order to express all measurements in terms of the same standard, the different values found have been reduced by the author to those given by the porous cup voltameter, and these are given in the last column of the following table. The corrections used are those found by Richards and Guthe for the various types. Since, in most cases the exact conditions of the experiments are unknown, these corrected values will simply give a general idea of the agreement between different observers; therefore, it was thought unnecessary to take into account the possible effect of included mother liquid.

From this list it is seen that the results obtained so far are not very satisfactory. Redeterminations in absolute measure by using a reliable form of voltameter are highly desirable.

The electrochemical equivalent of silver may also be expressed in terms of the electromotive force of the standard cell, *i. e.*, by comparing the electromotive force of the cell with the potential difference produced by the current at the terminals of a known resistance. The electrochemical equivalent will depend upon the value chosen for the electromotive force of the standard cell. The legalized value for the Clark cell is 1.434 volts. But this is probably too high. In Germany the electromotive force of the Clark cell is derived from silver voltametric measurements, and the Reichsanstalt has chosen as the working value 1.4328 volts at 15° C. In the following table the electrochemical equivalent of silver is calculated, as well for an electromotive force = 1.434 as for 1.433 volts:

TABLE II.

Observer.	Year.	Electro-chemical Equivalent. E = 1.434 Volts.		E = 1.433 Volts.	
		Usual Type.	Porous Cup V.	Usual Type.	Porous Cup V.
		mg.	mg.	mg.	mg.
Carhart[1]	1882	1.1172	1.1167	1.1180	1.1175
Rayleigh and Sidgwick	1884	1.1183	1.1178	1.1192	1.1187
von Ettinghausen[2]	1884	1.1180	1.1175	1.1188	1.1183
Glazebrook and Skinner	1892	1.1183	1.1178	1.1191	1.1186
Perot and Fabry[3]	1898	1.1193	1.1188	1.1120	1.1196
Kahle	1898	1.1173	1.1167	1.1180	1.1175
Guthe	1904	1.1174	1.1168	1.1181	1.1176

[1] Carhart, *Am. Journ. Sci.*, vol. 28, p. 374, 1884.
[2] Von Ettinghausen *Zeit. f. Electrotechnik*, vol. 2, p. 484, 1884.
[3] Perot and Fabry, *Ann.* Fac. des Sci. Marseille, vol. 8, p. 201, 1898.

In the case of Perot and Fabry, who used a Clark cell at 0° C. and found its electromotive force to be 1.4522 volts, using 1.118 mg. as the electrochemical equivalent, the difference of 0.0164 volt given by the Reichsanstalt has been used to reduce to 15° C., instead of the ratio given by them. The latter would give 1.1180 mg. in the first column and corresponding values in the others, and make the agreement with the earlier experiments a very close one.

The large differences between the earlier and the more recent comparisons can hardly be due to the silver voltameter alone. Doubtless the Clark cell comes in for its share.

Dr. Guthe concluded by emphasizing that as far as accuracy and the possibility of exact reproduction of the instrument are concerned, the silver voltameter is as good a standard instrument as a standard cell; however, the latter may win out finally for practical reasons.

The paper elicited an animated discussion. Dr. R. T. Glazebrook emphasized that in using the results of former investigators, one should always take into account the special form of voltameter used by them; he then gave a summary of recent work done in this field by the (British) National Physical Laboratory. Dr. W. D. Bancroft suggested to try the use of a revolving cathode inside a porous cup; the method works admirably for analysis and permits the use of much higher current densities than were formerly employed; why should it not be useful for the voltameter? In a reply to a question of Mr. S. S. Sadtler how silver nitrite behaves as electrolyte, Dr. Guthe said that he never used it. Prof. H. S. Carhart spoke of his early experiments with the silver voltameter and expressed the belief that it is not as good as a standard cell.

A Study of the Materials Used in Standard Cells and Their Preparation.

A paper on this subject was then read by Prof. Henry S. Carhart, of the University of Michigan; it consists of two parts, the first part, by Prof. Geo. A. Hulett, dealing with the chemistry of mercurous sulphate and its preparation for use in standard cells, the second part, by Prof. Henry S. Carhart, giving exact instructions for the preparation of the various materials and the construction of standard cells. A preliminary account of these investigations, given in a former paper of Prof. Carhart, has already been noticed in our May issue, 1904 (vol. II., page 176).

The preliminary work with Hg_2SO_4 consisted in testing various samples from the point of view as their use as a depolarizer. In each leg of an H cell was placed mercury, and the cell was then filled to above the cross-bar with dilute H_2SO_4; with mercurous sulphate on the mercury there was no e. m. f., provided the Hg_2SO_4 in each leg was from the same sample, but different samples generally gave an e. m. f. Electrolytically prepared Hg_2SO_4 was taken as standard and all others compared with it. Preparations of well-known makes differed markedly often by 0.001 volt.

Dr. Hulett dealt at some length with the equilibrium between mercuric ions, mercurous ions and metallic mercury. Since there is relatively little mercuric mercury in a solution which is in equilibrium with mercury, and since the mercuric sulphate is more soluble than the mercurous, then if we bring the system Hg-salt-solution to equilibrium, the salt cannot contain mercuric sulphate, but will be only mercurous sulphate.

Dr. Hulett then deals at some length with the hydrolysis of Hg_2SO_4, which takes place as follows:

$$3Hg_2SO_4 + 2H_2O = (HgOH)_2Hg_2SO_4 + 2HgHSO_4.$$

A liter of water hydrolyses 1.75 gm. Hg_2SO_4 leaving 0.90 gm. of $(HgOH)_2Hg_2SO_4$ as a residue while 0.68 gm. $HgHSO_4$ go into solution. This hydrolysis must be strictly avoided with standard cells, and Dr. Hulett gives the results of experiments as to the concentration of sulphuric acid which would prevent hydrolysis.

The rules as to the preparation of mercurous sulphate, based on Dr. Hulett's results, are given by Prof. Carhart as follows: In a flat-bottomed glass vessel (Fig. 4) is placed pure mercury about 2 cms. deep. It is covered with dilute sulphuric acid to a depth of 8 or 10 cms. The acid is prepared by adding one part by volume of concentrated H_2SO_4 to six parts of distilled water. Hydrolysis of mercurous sulphate does not take place in the sulphuric acid solution of this concentration. The solution is electrolyzed by making the mercury anode and a piece of sheet platinum hung in the acid the cathode. A current density of about 0.5 ampere per 100 square cms. surface of mercury may be employed. As soon as the current begins to flow a crystalline mercurous sulphate forms. A stirrer, consisting of a glass rod bent at right angles at the bottom, must be used to keep the surface of the mercury exposed and to stir the solution and the salt formed; it should be driven rapidly by a motor. A little over 4 grams an hour can be prepared in this way with a current of half an ampere. The apparatus should be kept covered with black paper or black cloth, since mercurous sulphate darkened by exposure to light gives too high an e. m. f. If the stirring is continued after the circuit is broken, the crystals of mercurous sulphate increase in size and become whiter. The mercurous sulphate may be removed from the mercury by means of a separatory

funnel, but it should be kept under the 1 to 6 acid solution, in contact with mercury, and in the dark.

Prof. Carhart also gives exact instructions on the preparation of the other materials used in standard cells, and on the method of setting them up (see our May issue, page 176). He also gives the results of a great many tests of cadmium cells. The e. m. f. of the Weston cadmium cell, with electrolytic mercurous sulphate, after equilibrium is reached, is 1.01907 or 1.01908 volt at 21.1° C. The agreement between the various cells, after electrical equilibrium is reached, appears to be excellent. In the discussion which followed, Dr. T. R. Glazebrook referred to experiments made in the (British) National Physical Laboratory; they have experimented with three different methods of preparing mercurous sulphate; one of these is Carhart's method; the three methods appear to yield

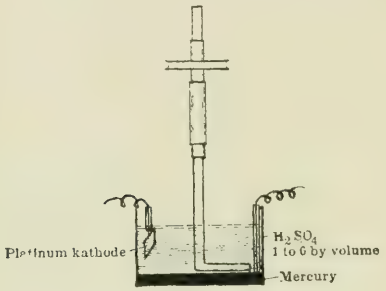


FIG. 4.—ELECTROLYTIC PRODUCTION OF MERCUROUS SULPHATE.

identical results. (See an abstract on this subject in the Synopsis of Articles in Other Journals, in this issue). Prof. Bancroft pointed out that this work of Carhart and Hulett shows that we have here a strictly reversible electrode. There exists experimental evidence tending to prove that the calomel electrode is not strictly reversible, although it is generally used as such. The maximum surface tension method ("Tropfelektrode") does not give us true single potential differences.

Electrometallurgy of Iron and Steel.

A paper on this subject was then presented by Dr. Paul L. T. Heroult, of La Praz, France. In the introduction the author pointed out that many inventors have proposed processes in this field, but that some of these processes are only theoretical conceptions, more or less practical, but existing only on paper. Commercial results furnish the best criterion, and from this point of view, the author says, the Société Electrometallurgie Française de Froges is the only concern which has, during the last two years, really manufactured and put on the market a complete series of carbon steels of a quality equal to or better than the best tool steels known.

The author makes a few remarks on his manufacture of ferrochrome. The walls of the crucible are made of ferrochrome ore, and two electrodes drop into the slag above the bath. The metal thus never comes into contact with carbon. Thus, the reducing carbon being exactly proportioned, it is possible to obtain soft metals, that is to say, metals almost entirely free from carbon.

Concerning the reduction of iron ores and the manufacture of steel he says that it would not be advantageous to perform the different operations—reduction of the ore and refining of the metal—in one and the same apparatus. First, pig iron is made in a special electric crucible. This operation takes place without any special difficulty, providing the indispensable precautions be taken in the arrangement of the charge and in carrying out the operation.

In a general way, the author points out, it is not advantageous to transform electrical energy into heat for the reduction of a so easily reducible ore as iron. Since electric heat is very costly, it must be economized to the fullest extent. Dr. Héroult refers to two means of economizing the electric heat. One is his "economizer." This device is based upon the principle of combining the total amount of oxygen contained in the ore with carbon to CO. This CO is subsequently burned by admitting the necessary amount of atmospheric air. The heat generated in this last operation is used to heat the ore previous to its reduction. As a matter of fact, this ore falls into the reduction chamber in the molten state. The amount of electric energy necessary for carrying out the operation is theoretically nil, although in the experiments made in practice it amounted to quite a considerable quantity, on account of losses by radiation. This process did not prove entirely satisfactory, owing to the great difficulty of preventing the walls from corroding, and also to the consumption of the reducing carbon which is large.

The second process described by Dr. Héroult and stated to have been successful, consists in reducing one-half of the ore in the molten state, while the other half is reduced in the solid state by means of the CO evolved by the first half. "If one makes the calculation of the heat units absorbed by the reduction and the heat units evolved by the burning of the carbon in the form of CO_2, one can easily perceive that the quality of electricity needed is very small."

Dr. Héroult then said he would not further discuss the manufacture of pig iron, "because the electric process, though very interesting, is only applicable under certain conditions, and is not likely to supersede the blast furnace, except where electrical energy is extremely cheap." He then discussed his electrical steel process. This process, which is worked at La Praz, France, and at Kortfors, Sweden, produces steel stated to be of a quality equal to and superior to the best crucible cast steel. The quality of the raw material from which it is made, is a matter of indifference. For instance, steel containing about 0.01 sulphur and 0.01 phosphorous is being made out of raw materials, scrap, that contains 0.15 sulphur and 0.30 phosphorous. The electric furnace has enabled the metallurgist to get rid once for all of the necessity of choosing beforehand his raw material and paying for it a high price. The de-phosphorizing of metals was well understood, although the facilities afforded by the electric furnace are such that it was rendered possible to attain in one operation the results above referred to. The process of desulphurization, which, up to the present time has always been considered unsafe and erratic has been brought by Héroult to a high degree of perfection. By means of the electric furnace he has the entire operation in perfect control. He can regulate the temperature as he chooses and carry out the work without any oxidation from the air.

He makes the claim that at a cost not exceeding one-half a dollar a ton, he can make out of any steel delivered in the molten state, that is, as tapped out of a Siemens furnace or a Bessemer converter, a metal of any desired composition, containing less than 0.01 sulphur and 0.01 phosphorus. The electric process must not be considered as a steel-making process, but as an adjunct to existing plants and apparatus. By means of this electrical adjunct the commercial value of the product can be greatly increased.

The author says, there will be in future no excuse for not making steel free from impurities such as sulphur and phosphorus. He is far from predicting that the electrical furnace process will supersede the old metallurgy, but "it will and must cause a revolution so far as the quality of the metal used in the industries is concerned." (Concerning details of the Héroult steel process the reader may be referred to descriptions on pages 63, 287, 449 and 467 of vol. I. of this journal.)

In the discussion which followed the paper, Prof. J. W. Richards spoke quite enthusiastically on Dr. Héroult's work. He pointed out that when we consider the finer grades of steel which are very expensive at present, the cost of the electric refining process is of little account. He predicted that

industrial developments in this field will soon set in, first in Canada and then in the United States. The electric furnace will then be used as an adjunct to the open-hearth furnace, to take off the peak of the load, *i. e.*, to furnish electrically the last few hundred degrees to bring the metal to the melting, point while the combustion of gas furnishes the lower range of temperature. We are now in a period of transition in the steel industry.

Mr. Woolsey McA. Johnson said that the only criterion of a successful metallurgical process is its operation on a large scale, as accomplished in the case of Héroult. The use of the electric furnace for refining steel is another example of the general rule, that in metallurgy electrochemical methods are specially useful for the finishing reactions. Mr. Edstrom spoke briefly on the suitability of the process for Sweden, with its abundance of water-power.

The Present Status of the Edison Storage Battery.

A paper on this subject, by Prof. A. E. Kennelly and Mr. S. E. Whiting of Harvard University, was "presented on behalf of Mr. Thomas A. Edison, as a brief synopsis of the results obtained with his storage battery up to the present date." It was read by Mr. Whiting.

The authors give some historical notes on the development of the battery and especially on the so-called types C, D, E, of which E is the latest one. E-18 has 12 nickel plates and 6 iron plates. The weight of this cell complete is 12.66 lbs. (5.75 kilos). The normal rated delivery of these cells is 114 ampere-hours, which is practically the same at either the 30-ampere or 120-ampere discharge rate. At the 30-ampere rate (3.8 hours), the mean potential difference to 0.75 volt is 1.234 volts, representing an output of 141 watt-hours or 11.1 watt-hours per pound (24.6 watt-hours per kilo). At the 120-ampere rate (0.95 hour), the mean potential difference to 0.75 volt is 1.04 volts, representing an output of 118.5 watt-hours or 9.38 watt-hours per pound (20.7 watt-hours per kilo). Although the above are the normal rated capacities, the full capacity of the cell is found to be about 140 ampere-hours, which makes the total output at 30 amperes, 173 watt-hours and at 120 amperes 145 watt-hours; or the specific output 13.7 watt-hours per pound (30.2 watt-hours per kilo) and 11.5 watt-hours per pound (25.4 watt-hours per kilo) at the two rates, respectively.

The authors then give some details on the construction of the cells of type E (see Electrochemical Industry, January, 1904, vol. II., page 36). The cell is now manufactured in three sizes stated in table III.

The authors discuss briefly the chemical theory of the cell and then describe the discharge curve of e. m. f. which has the following peculiarities:

(1) An initial period of rapid descent occupying about 10 per cent of the delivery period.

(2) A nearly steady gradient of gradual descent continuing until within about 10 per cent of the end of the whole delivery period.

(3) A final period of rapid descent occupying the last 10 per cent of the delivery period (assumed as stopping at a potential difference of 0.75 volt).

The initial e. m. f. is influenced by the previous history of the cell, more particularly by the time which has elapsed since the close of the preceding charge. The range of initial e. m. f. is between 1.35 and 1.65 volts. It would seem that this e. m. f. depends upon the amount of gases remaining after the charge, occluded in the pores of the cell.

The e. m. f. at and near the end of the discharge is also somewhat variable, depending in some measure upon the rate and nature of the discharge. It clearly accompanies the exhaustion of the active materials.

In the intermediate stage of the discharge, the gradient of descent is substantially uniform and approximately independent of the discharge rate within the usual working limits. This diminution of e. m. f. may possibly be due to the increasing thickness of the layer of effete material formed by the progressive exhaustion of the active material.

If the curve *a b c d* (Fig. 5) be integrated, the mean ordinate is found closely to approach the actual ordinate at *C* or the point of half delivery. This means that a straight line *A C D* may be chosen nearly coinciding with the steady gradient of the actual curve *bc*. This is shown in a dotted line *A C D* in the figure. The area above this line *A a b* at the beginning, is approximately equal to the area below the line *c D d* at the end. These areas represent, therefore, sensibly equal and opposite quantities of electrical energy, with respect

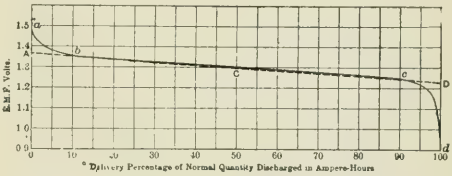


FIG. 5.—DISCHARGE OF EDISON BATTERY

to the curve *a b c d*. Consequently, we may for practical purposes replace the actual curve *a b c d* by the equivalent straight line *A C D*, which is represented by the formula

$$e = 1.37 - \frac{x \times 0.14}{100} \text{ volts}$$

where x is the percentage already yielded, of the full delivery. The mean discharge e. m. f. is, therefore, 1.30 volts. This approximation greatly simplifies practical computation with the Edison battery.

The internal resistance of an Edison Type E cell is substantially constant during the main working portion of the discharge corresponding to *bc* in Fig. 5. Thus in the E-18 cell, the internal resistance at ordinary temperatures is about 0.0022 ohm. This would correspond to 0.0278 ohm in a Type E similar cell weighing one pound; or to 0.0126 ohm in a cell weighing 1 kilo. The internal resistance is slightly less at the beginning of the discharge, but becomes considerably greater near the end of the discharge. Since however, this rise in resistance occurs only during a small portion near the end of the delivery, its effect in the total discharge may be neglected for most practical purposes.

The internal resistance does not vary greatly with the discharge rate within the usual working limits of 0 to 150 amperes. In other words, the drop of pressure in the cell is approximately proportional to the discharging current strength.

The maximum amount of power which may be obtained

TABLE III.

Type.	Positive Plates.	Negative Plates.	Capacity in Ampere-Hours. Normal.	Capacity in Ampere-Hours. Maximum.	Normal Charging Current. Amp.	Normal Charging Time. Hours.	Weight Complete in Kilograms.	Dimensions over all (Excluding Trays). Length in Cms.	Breadth in Cms.	Height in Cms.	Volume in Cubic Cm.
E-18	12	6	110	140	40	3.75+	5.66	13.0	6.6	33.5	2,874
E-27	18	9	165	210	60	3.75+	7.95	13.0	..	33.5	....
E-45	30	15	275	350	100	3.75+	13.6	13.0	..	33.5	....

from a cell in an external circuit is obtained if the resistance of the external circuit equals the internal resistance of the cell. For an E-18 cell this condition of maximum power corresponds to 15.15 watts per pound (33.4 watts per kg.), corresponding to a discharge rate of 296 amperes (less than half an hour). The practical rate of power delivery at 150 amperes corresponds to 11.5 watts per pound (25.4 watts per kg.), which is on a par with the full-load output of good dynamo machines.

The energy liberated in an E-18 cell is 1.3 volts × 141 ampere-hours = 183.3 watt-hours or 14.48 watt-hours per pound (31.9 watt-hours per kg.) and this liberation of energy is constant to a first approximation for all rates of discharge within the working limits. The amount of this liberated energy which is delivered in the external circuit depends only on the electrical efficiency of the circuit, or on the drop of pressure in the cell. Thus, at 90 per cent electrical efficiency, or 10 per cent internal drop (corresponding to about 60 amperes in the E-18 cell), the externally delivered energy would be 183.3 × 0.9 = 165 watt-hours.

It can be shown that if any Edison Type E battery, in any grouping of cells, be discharged at the rate of p watts per unit mass, reckoned at the mean voltage of discharge, the electrical efficiency, of the battery circuit will be $\frac{1+\sqrt{1-n}}{2}$, where $n = \frac{p}{P}$ and P is the maximum power per unit or mass or $\frac{e^2}{4mr}$, where m is the mass of a cell, e the actual e. m. f. and r the internal resistance.

Thus, if a battery of 68 Edison Type E-18 cells be discharged at 120 amperes or 124.3 average external watts, the total external power will be 68 × 124.3 = 8454 watts, and the total weight being 861 pounds, the power rate per pound taken from the battery is 9.83 watts. The maximum power rate is, however, 15.15 watts per pound as above; so that the ratio $n = \frac{9.85}{15.15} = 0.65$. The electrical efficiency of the battery circuit is, therefore,

$$\frac{1+\sqrt{1-0.65}}{2} = 0.796$$

or 79.6 per cent. The delivery per pound of battery will, therefore, be 14.5 × 0.796 = 11.5 watt-hours per pound, and the entire battery will deliver 9900 watt-hours to the external circuit, when discharged to 0.75 volt potential difference per cell.

The charging e. m. f. of an Edison cell is approximately 1.6 volts (somewhat greater at the outset) until about 60 per cent of the charge has been stored, when it rises to about 1.75 volts, simultaneously with increased evolution of gases. This rise is, therefore, apparently connected with gaseous polarization. To the e. m. f. of the cell must be added the drop in internal resistance, in order to find the potential difference at charging terminals. The mean e. m. f. of the cell during charge may, therefore, be taken as roughly 1.67 volts. The resistance of the cell during charge is approximately the same as during discharge, being greater at the outset of the charge, corresponding to the condition of resistance at the end of the discharge.

During the charge of Edison cells, bubbles of gas are liberated at both plates, oxygen at the anode or positive plate, and hydrogen at the cathode or negative plate. The collected gases form an explosive mixture. In the ordinary charging process there is a distinct evolution of gas at the outset, which reaches its maximum in about a quarter of an hour. The gassing then decreases to a lower steady value, which continues until about 60 per cent of the charge, after which it rapidly rises to a steady much higher value than at first. The electrical energy expended in the liberation of these gases is practically all lost.

To replace the water thus lost by decomposition during charging, a small quantity of distilled water has occasionally to be added to the cells through a filler conveniently adapted to this purpose.

Since the mean electromotive force of discharge is approximately 1.3 volts, and the mean electromotive force of charge approximately 1.67 volts, it follows that the superior limit of watt-hour efficiency in an Edison cell is $\frac{1.3}{1.67}$ or 78 per cent. In practice it is always less than this, due to internal drop.

The efficiency may best be examined first in relation to the voltage of charge and discharge, and second, in relation to the electric quantity charged and discharged.

1. If there were no drop of pressure due to internal resistance, either in charging or in discharging, and all the electricity charged in the cell (as expressed in coulombs or ampere-hours) were discharged, the ampere-hour efficiency of the cell being thus 100 per cent, the watt-hour efficiency would be 78 per cent or thereabouts. This figure can, in fact, be approached by employing very low rates of charging and discharging; *i. e.*, by taking many hours to each process. On the other hand, the more rapid the charge and discharge, the greater the IR drop in the cell, and the less the efficiency, even on the assumption of 100 per cent ampere-hour efficiency. Thus at 60-amperes charging and discharging rates, the potential difference in charge would average about 1.8 volts in the E-18 cell and the potential difference in discharge would average about 1.17 volts to the 0.75 volt limit, representing a watt-hour efficiency of 65 per cent, with 100 per cent ampere-hour efficiency.

2. The Edison cell would manifestly possess an ampere-hour efficiency of 100 per cent if no gases or irreversible substances were generated in its cycle of chemical action. Thus if a certain number of grammes of iron were reduced and a certain number of grammes of nickel were oxidized by one ampere-hour of charging current, and no other action took place, then on discharge the reconversion of these masses of active material would develop the complete ampere-hours of electricity. On the other hand, every gramme of hydrogen (or the equivalent mass of oxygen) liberated and discharged from the negative plate during charge absorbs 26.8 ampere-hours of electricity, which is not returned to the circuit during discharge. The ampere-hour efficiency of the Edison cell is, therefore, determined by the amount of gas escaping during the charge. This in turn depends upon the rate of charge, or charging-current strength, since the greater this strength the greater the drop in internal resistance, and the sooner the plates are brought to that difference of potential at which the water is rapidly decomposed.

At high rates of charge, then, the watt-hour efficiency of the cell must fall off, not only because of the voltage drop, but also on account of the reduction of ampere-hour efficiency in gasification.

Nevertheless, in many cases, and particularly in automobile work, this sacrifice of energy is amply warranted by the convenience and saving of time effected by rapid charge. The normal charging time of Edison E cells is about four hours. In cyclical charges and discharges of four hours each, the ampere-hour efficiency is about 75 per cent and the voltage ratio 70 per cent, so that the watt-hour efficiency may be taken in round numbers at 50 per cent (0.75 × 0.7 = 0.525). It is possible, at a still greater sacrifice of efficiency, to charge the cell at fully double the above normal rate.

The authors then give a summary of the results of various tests of the Edison battery, mostly made abroad; these results have already been given in our columns (v. II., p. 40, 118). It is also stated that much experience has been attained in actual service from the Edison battery on automo-

biles, and that this experience has led to the elimination of some of the minor practical difficulties that any new battery always encounters. It is stated that the Edison battery appears to be so durable that no electrical depreciation is discernible in the cells during the three years' total experience of the practical construction of the battery. No mechanical corrosion of the plates or pockets has been discernible during that time and no depreciation seems to have yet occurred in the active material, judging from the capacity tests of cells which are stated to be as great at the present time as they were when the cells were first constructed. The authors have recently confirmed this observation in the case of Type D cells that have run nearly 3000 miles in an automobile of the Edison Company in Boston. The capacity of these cells was found to be equal to that of new cells of the same type. Two of these cells were opened for examination and the sediment in them collected and dried. The dry sediment weighed 3.9 and 7.1 grams respectively, probably less than one-third of 1 per cent of the active material in the grids. In fact, a new cell freshly set up will show about this quantity of material washed by the solution from the external surface of the plates. No signs of depreciation or corrosion appeared on any of the plates or connections.

According to observations at the factory, Edison cells lose 15 per cent of their ampere-hour charge in eight weeks of idleness; somewhat different figures have been obtained in other tests. But all tests show that the cells are remarkably immune from deleterious effects due to careless treatment. Cells have been allowed to dry out, have been permanently short-circuited or even charged in the wrong direction. These cells have shown a full restoration of their capacity after a prolonged restoring normal charge.

The conclusions reached by the authors are that "the Edison nickel-steel alkaline storage cell, in its large output at heavy discharge rates, its low depreciation in capacity and its durability under severe and adverse treatment, approaches the capabilities of a piece of mechanical apparatus more nearly than is ordinarily credited to electrolytic structures. For this reason it is specially adapted to automobile service, where the treatment is abnormally arduous and severe."

In the discussion which followed, Prof. C. F. Burgess gave the results of some tests made by two of his students in his laboratory in the University of Wisconsin on Edison cells taken from automobile service; the efficiencies obtained were below 50 per cent; attention was also called to the fact that gas is also developed during the discharge of the cell. Dr. A. E. Kennelly pointed out that in the Edison cell an approach is made to the steel structure in dynamo construction. We have here a steel structure which resembles the steel structure in machines devoid of electrolyte, the figures of power per weight being of the same order of magnitude as for good dynamos. The battery has a low efficiency, but it has the great advantage of being nearly fool-proof. Replying to a question of Mr. S. S. Sadtler, Mr. Whiting described how the cell is practically sealed so that no air can reach the electrolyte, which would result in the formation of carbonate.

Electrolytic Conduction.

A paper on this subject was then presented by Prof. Joseph W. Richards, of Lehigh University, who, in his introductory remarks, said that it is sometimes good to go back to fundamental principles; his paper is intended to reconsider the problem of the mechanism of the conduction of the electric current through electrolytes. According to the ionic hypothesis, electrolytic conduction is *per se*, in the body of the electrolyte, different in nature or kind from metallic conduction, in which we know that there is no migration of ions or carrying of the current by the convective action of charged ions.

The object of Dr. Richards' paper is to present the thesis that, as far as the conduction of electricity through the body of the conductor is concerned, there is, as far as we can determine, complete identity between metallic conductors and so-called electrolytic conductors.

After having referred to Marvin's experiments on induced currents in electrolytes without the use of electrodes and on Richards' and Landis' experiments on the electrolysis of sulphuric acid solutions with very small currents, the author presents the following argument. Many solid chemical compounds are conductors of electricity; in fact, the majority are. They are, in this condition, undoubtedly conductors in the ordinary sense of possessing metallic conductivity. No scientist ascribes a different kind of conductivity or a different mechanism of conduction to a solid copper bar from a liquid column of mercury. In fact, liquid mercury is used as the standard of resistance of metallic conductors. There is no sharp change in electrical conductivity when a metal melts, which again points to the identity of metallic conduction through solid or liquid metals. Similarly, there is no sharp change in conductivity when a solid conducting salt melts; it becomes a liquid conductor at the melting point without change in conductivity, just as metals do. The conclusion is that there is conductivity of the same nature in a fluid salt as in a solid salt, and as in a metal, viz., metallic conduction.

Since a solid salt conducts metallically, and a fused salt electrolytically; that is, with accompanying electrolysis, the author concludes that if the mechanism of the conduction through the body of an electrolyte is mere metallic conduction and nothing else, then, the electrolysis is a thing apart from the mechanism of the conduction. He, therefore, claims that the electrolytic or electro-chemical phenomena accompanying the passage of the current are matters occurring only at the electrodes, and have no rational connection with the mechanism of the transmission of the current through the body of the electrolyte.

Dr. Richards then describes the following experiment. A narrow glass tube about 12 inches long is turned up at the ends, so as to leave about 6 inches straight tube in the middle. It is warmed, and melted zinc chloride (M. P. 262° C.) poured into it. A Bunsen burner is kept under the middle, to keep it melted, and two zinc rods are plunged into the melted salt in the upturned ends, where the salt at once sets. The cell is now constituted as follows: Zinc—Solid $ZnCl_2$ — Melted $ZnCl_2$ — Solid $ZnCl_2$ — Zinc. Asbestos screens are slipped over the tube so as to define sharply the boundary line between solid and fused salt.

When the temperature is steady for some time, a thermopile is connected with the terminals, a delicate galvanometer reading to microamperes being put into the circuit. The following facts were established: (1) For e. m. f.'s up to 3.5 volts, the current passing is proportional to the applied e. m. f. (2) On removing the impressed voltage, there is no trace of back e. m. f., in any case. (3) On continuing a current of 50 to 100 microamperes 15 minutes, there is no trace of electrolysis, either by the formation of gas or metallic deposit or "metallische Schliere" at the junction of the liquid and the solid electrolyte or at the metallic terminals.

The experiment proves to the author, taking it in connection with the preceding observations, that the liquid salt acts merely as a simple conductor of the same nature as metallic conductors, and by a similar mechanism, and that the question as to whether electrolysis or electrochemical action takes place is a matter entirely independent of the mechanism of electric conduction through the body of the electrolyte. At any rate, the passage of electric current from solid zinc to solid zinc chloride, or *vice versa*, or from solid zinc chloride to fused zinc chloride, or *vice versa*, is not one of the conditions which produce electrochemical decomposition of the zinc chloride.

The author then asks: What is electrolysis, and where is its seat? It is electrochemical decomposition produced at the points where the electric current passes from a fluid compound conductor to a solid compound-conducting body, and its seat is the contact surface.

This transfer of energy is accompanied by an unloosening of chemical affinities, and while one constituent of the electrolyte is liberated, the other is potentially freed. This potentially free constituent sets up through the body of the whole electrolyte a condition of chemical stress or stress of chemical affinity, which is transmitted from molecule to molecule to the other electrode, where the complimentary constituent is potentially free. This chemical stress, exhausting itself in diffusion effects, and the primary cause of the migration phenomena, is chemical in its nature and not electrical, and is *caused* by the transfer of the electrical energy at the surface of the electrodes. The migration phenomena are, in this view, secondary chemical effects of the transfer of the current energy at the surface of the electrodes, and are not, in any way, phenomena inseparably connected with the mechanism of the transfer of electric current through the body of the electrolyte. While electrochemical action is produced directly by the current at the surface of the electrodes, the means of communication between the two electrodes by which the continuance of that action is preserved is in no sense by means of convection currents of charged ions, but is by means of chemical stress transmitted entirely independently of the mechanism of the conduction of the current through the body of the electrolyte.

The paper elicited a long discussion, in which Messrs. Hering, Roeber, Patten, Bancroft and Kahlenberg participated, all of which pointed out that the one experiment, quoted by Dr. Richards, in support of his theory, could not be considered a sufficient proof; the current used is so small and the time so short that one would not be able to detect the products of electrolytic decomposition; while the other observations made by the author present nothing unusual. Dr. Kahlenberg remarked that similar views have formerly been expressed by others; thus, Mr. C. J. Reed has expressed the belief that if, instead of removing a metal from a solution by electrolytic deposition, one would remove the metal by some other means from the solution, the concentration changes resulting in the interior of the electrolyte would be the same.

Electrolysis of Fused Salts.

A paper by Prof. R. Lorenz, of the Institute of Technology of Zurich, was then presented on this subject. In the absence of the author it was read in abstract by Dr. E. F. Roeber.

The author makes some introductory general remarks on the difficulties in the preparation of the electrolyte, and on the difficulties of devicing a suitable vessel. For instance, for the electrolysis of fused zinc chloride, a porcelain vessel would be absolutely unsuitable; there would be no normal electrolysis. An apparatus of wide applicability is the wrought-iron V-formed electrolyzer of Helfenstein. (Fig. 6.) The reasons for the construction in V form will be given later. The main requirements for any apparatus of this kind are: It should be easy to handle and it should be possible to maintain the temperature constant. The V-formed electrolyzer is good for all work in the laboratory. For temperatures up to about 700° C. refractory glass is used, beyond that temperature porcelain.

The author then discusses at length some peculiar phenomena which are characteristic for the electrolysis of fused salts. It is an exception if, without special precautions, the electrolysis is normal, *i. e.*, in accordance to Faraday's law. To point out the disturbing elements in the electrolysis of fused salts, the author gives two examples.

First, electrolysis of lead chloride. Faraday himself showed that his law is fulfilled in this case; but he could prove this only by using a molten lead cathode. If a V-tube is used, with carbon electrodes, and a temperature of 600° to 700° C., the cathodic compartment soon assumes a dark color, while the anodic compartment is yellow and clear. There appears a very important phenomenon, the formation of metallic mist in the salt near the cathode. This may be either a real solution of the metal in its fused salt, or a mechanical suspension of the metal in finely powdered form. This phenomenon depends to a considerable extent on the temperature and vapor tension. From experiments made by Lorenz and Auerbach it seems possible that we have here in fact a real solution of the metal in the fused salt. A reguline deposition of the metal at the cathode takes place only when the fused salt is nearly saturated at the cathode with the metallic mist.

When the metallic mist comes in contact with the anode, it acts as a depolarizer and prevents the development of chlorine; the original salt is then simply reformed or regenerated.

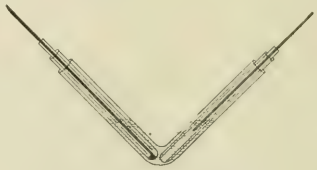


FIG. 6.—APPARATUS FOR ELECTROLYZING FUSED SALTS.

With small current densities this phenomenon may become so prominent that the salt conducts the electrical current apparently like a metal does.

The second example discussed by Lorenz is electrolysis of zinc chloride. There we have not only the troubles due to formation of mist, but troubles due to basicity. There are two kinds of commercial zinc chloride. One kind is suitable for electrolysis; the other is not. The trouble is due to the content of water. A content of even less than 0.78 per cent of water is detrimental. Lorenz and Gruenauer removed the water from the molten zinc chloride by means of hydrochloric acid gas; if certain conditions are maintained, one gets $ZnCl_2$ in a condition in which it may be easily electrolyzed.

The author then dealt with Faraday's law in the electrolysis of fused salts. The formation and the movements of the metal mist through the bath cause the deposit to be less than fallows from Faraday's law. The ampere-hour efficiency is the higher the better the action of the mist is prevented—this may be more or less accomplished by removing the two electrodes from each other, by making the apparatus of such cross-section that diffusion is prevented—by using a high-current density—by using a relatively low temperature.

The main point would be to prevent completely the formation of the metallic mist. Lorenz and Appelberg have found that there are in reality substances which, when added to the bath, prevent the formation of the mist entirely. The author thinks this is an important point for industrial applications, for instance, manufacture of aluminium. Secondly, if mist is formed we must try to prevent its diffusion. This is done by the V-tube. By carefully enclosing the electrodes, we can get an ampere-hour efficiency of nearly 100 per cent. The only disadvantage of this apparatus is its high resistance.

Now, if a certain apparatus is used, and if the temperature is maintained constant, then if we vary the current, the ampere-hour efficiency decreases with decreasing current and it becomes zero, before the current itself is zero. There is the empirical relation $\text{efficiency} = 100 - \frac{k}{i^n}$, where i the current and k and n constant figures depending on the construction of the apparatus and the temperature. This formular is very exactly fulfilled.

In the beginning of the electrolysis, the ampere-hour efficiency of the anodic reaction is not the same as that of the cathodic reaction, but they become equal if the electrolysis is continued for a sufficient length of time. In the beginning, less chlorine is developed; this is because the carbon anode is being saturated with chlorine.

The author then discussed the phenomena of counter e. m.

f. and polarization. The polarization also depends on the mist formation. As soon as the mist reaches the anode, it acts as a depolarizer. For lead chloride at 600° C., the normal polarization e. m. f. is 1.2 volts. If the metal mist, however, reaches the anode, the e. m. f. decreases at once to 0.6 or 0.8 volt. As soon as the mist is again cut off from the anode, the e. m. f. rises again to its normal value. This is shown in Fig. 7. There is a complete parallelism between the phenomena of ampere-hour efficiency and polarization.

Caustic soda shows two values of polarization, one 2.14 to 2.19, the other 1.3 to 1.1. One point corresponds to metallic sodium at the cathode against oxygen at the anode. The other point corresponds to hydrogen at the cathode against

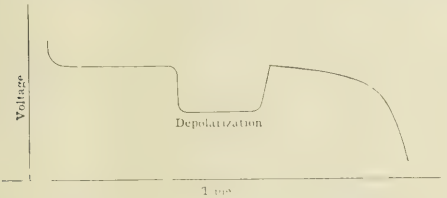


FIG. 7. DEPOLARIZATION CAUSED BY CONTACT OF THE METALLIC MIST WITH THE ANODE.

oxygen at the anode. The author finally showed that the Gibbs-Helmholtz rule is fulfilled, and gave some theoretical considerations. The paper was not discussed.

Electrolysis and Catalysis.

The last paper of the session was that of Prof. Wilhelm Ostwald, of the University of Leipzig, Germany. In the absence of the author, it was read and briefly discussed by Prof. W. D. Bancroft, who illustrated Ostwald's views by some examples. The paper is published in full on another page of this issue. There was no further discussion.

This completed the work of Section C of the International Electrical Congress. The members were, however, invited to attend the separate meeting held on Friday by the American Electrochemical Society.

Friday Session.

The Friday session was an independent meeting of the American Electrochemical Society, designated as a joint meeting with the (German) Bunsen Society and the (British) Faraday Society.

At the opening of the session, Dr. Hans Goldschmidt, of Essen-Ruhr, Germany, presented to the meeting the good wishes of the Bunsen Society in a felicitous little speech. He referred to the fact that the Bunsen Society and the Faraday Society have both selected their names from one of the most distinguished electrochemical scientists of their countries. Both Faraday and Bunsen had one peculiarity in common in all their researches. They placed the experiment and experimental evidence above everything. Faraday, while deeply religious and even inclined to mysticism, was most skeptical with respect to experimental evidence—especially if the experiments had been made by others. Dr. Goldschmidt then told an incident from his university life when he studied with Bunsen; he once proposed to Bunsen a simple modification of an analytical method which had given him correct results in five cases; but Bunsen called his attention to various details which might prove disturbing elements and suggested to him to come back with his simplified method when it would have given exact results in fifty cases under most careful consideration of all details. As a matter of fact, Dr. Goldschmidt said he did not come back to Bunsen with his method since scrutinous tests showed its weak points.

Dr. Goldschmidt then argued that both the Bunsen Society and the Faraday Society, by selecting their names, had indicated the spirit in which their members intend to work. Too often, Americans consider European electrochemists, especially those from Germany, as mere theorists (Denker and Dichter). However, the earnest endeavor to place experimental evidence above everything should be a strong connecting link between the two European electrochemical societies and the American Electrochemical Society, the work of which tends to achievements on a large industrial scale.

Prof. J. W. Richards, as a member of the Faraday Society, extended the good wishes of this society to the meeting, and expressed the regrets of several British electrochemists, who had intended to attend the meeting, but were detained in the last minute.

An Analytical Study on the Deposition of Aluminium From Ethyl Bromide Solutions.

A paper on this subject was presented by Dr. H. E. Patten, of the University of Wisconsin. The main results of the author's experimental investigation are as follows. Plotnikoff's values for the conductivity of aluminium bromide dissolved in ethyl bromide were found to be reliable; and his deposition of crystalline aluminium from such a solution was confirmed by the author. Crystals of aluminium bromide near 0.5 cm. on edge were formed from the fused salt; they belong to the rhombohedral division of the hexagonal system and resemble calcite. The purified aluminium bromide is not white, but very light yellow. Decomposition curves for dilute and concentrated solutions of aluminium bromide in ethyl bromide were determined by the author with platinized, and with polished platinum electrodes, as well as with aluminium electrodes. Aluminium has a single potential of + 1.10 volt against a 40.95 per cent solution (by weight) of aluminium bromide in ethyl bromide; and bromine, a single potential of — 1.20 volt.

A current density of 0.0023 ampere per square cm., or about 2 amperes per square foot, is just sufficient to compensate for the solvent action of the solution upon the deposited aluminium in a concentrated solution (40.95 per cent). A dilute solution (4.38 per cent) failed to yield aluminium even at moderately high-current density. An aluminium anode, which has been stripped of its film electrolytically, gave 2.235 volts in a 4.38 per cent solution of $AlBr_3$ in ethyl bromide against a platinum cathode. Similarly magnesium gave 2.227 volts, from which, by subtracting — 1.20 for bromine, we get + 1.08 volt as the approximate single potential of magnesium against this solution. A striking exception to the Nernst-Thomson rule is cited by the author in that ethyl bromide with a dielectric constant of 8.9 yields a solution of good conductivity with aluminium bromide as solute.

The investigation of the author has a bearing upon the phenomena of the aluminium anode. A film appears to be formed upon aluminium in a solution very free from oxygen; it can be removed by using the aluminium as cathode, but the higher counter e. m. f. mentioned by former investigators has not been found thus far by the author. Finally, though the results as to the electrolytic deposition of aluminium are theoretically very interesting, the author concludes that aluminium bromide, dissolved in ethyl bromide, lacks the requirements of a commercial plating solution for the deposition of aluminium.

In the discussion which followed, Prof. W. D. Bancroft spoke of the uncertainty of Ostwald's zero of potential used by the author; this is rather a matter of assumption or agreement, since we have no reliable method at present of measuring single potential differences. Prof. J. W. Richards expressed his interest in the paper on account of the use of a non-oxygen containing electrolyte for the deposition of aluminium.

Aluminium Rectifier.

A paper on this subject was presented by Prof. Wilder D Bancroft, of Cornell University. In the experiments seamless aluminium tubes bent in U-form were employed. They

were water-cooled. The other electrode was lead. Phosphoric acid was used as electrolyte.

When the current is gradually increased, the current efficiency starts very low about 50 per cent, and is later on pretty nearly constant, about 75 or 80 per cent. The power factor starts with 35 per cent and goes up to 90 per cent with increasing current. The watt-hour efficiency is low, starting with about 50 per cent and going down to 30 per cent. The author endeavored to explain some of these observations, although he said that the matter is not yet entirely cleared up. With ammonium phosphate solutions he had been told that much higher energy efficiencies can be obtained, but he does not yet see the reason for it. The paper is only a preliminary one and the author's investigations are to be continued.

In the discussion Prof. C. H. Burgess referred to his and C. Hambuechen's paper (Transactions American Electrochemical Society, Vol. I., page 147) in which he had endeavored to give a complete analysis of the losses in the aluminium rectifier. He referred to his view of electrolytic valves, consisting of openings in the protective coating which expand and contract according to the direction of the flow of current. Prof. Bancroft thought that this view of the valves had been exploded by more recent investigations made in England. Prof. Burgess replied that he still believed in his theory and referred to the photographic evidence of the condition of the surface of the aluminium electrode. Prof. Bancroft replied that this experimental evidence exists, but it is a different thing what to conclude from it; Burgess considers the whole current to pass through the perforations in the film, while Bancroft considers the perforations as a source of inefficiency of the film, the whole film being active.

Some Aspects of Applied Electrochemistry.

A paper on this subject was presented by Mr. Woolsey McA. Johnson, of La Harpe, Kas. The author makes the introductory remark that perhaps the title of his paper would be more appropriate were it given as Commercial Aspects of Electrochemistry. It is not crass and materialistic to look first upon any applied science purely in its industrial aspect. A metallurgical process should first of all make money for those who have put their capital in the enterprise. The late Prof. Eggleston, of the Columbia School of Mines, defined metallurgy as the art of making money out of ores. Thus, it is with any electrochemical proposition that the test of any process is its commercial efficiency. A process that does not fall in this category is as sad a sight as an abandoned New England farm. It has come into an existence for which it was never intended. A deserted smelter connotes to one's mind a feeling of sadness for the misplaced and misdirected energy, whereas, on the other hand, a well-managed and efficient plant like the Homestead Works of the Carnegie Steel Company, or one of the large electrolytic copper refineries has something grand and lofty about it like a play of Shakespeare's or an opera of Wagner's. Viewed in its widest relations, practical science is not only compatible with the use of the imagination, but for the greatest development in this line the highest imaginative and creative powers are necessary.

Mr. Johnson remarked that there are certain principles of economics and certain principles of applied science which hold good for any branch of practical work. A metallurgist combines different agents and different forms of apparatus to produce his desired effect. To wit: Large production with high recovery of values and a pure product. He is also under the stress to do this commercially. Thus, it will be seen that the laws which govern metallurgical operations are really when viewed in perspective, the combination of certain scientific and economic truths. It may be said that applied science amalgamates two studies, economics and natural science.

One of the first things in starting up any new proposition that is to compete with an old and established process is that it is of prime importance to know the defects and good points of the old business. The question of the cost of raw material, the cost of treatment per ton of raw material, the usual losses, the purity of the product which is demanded by the present market should be known with exactness. Such a knowledge will show the weak points of the old metallurgy and many a football game has been won by hammering at a weak tackle. As has been said, the new proposition should make an attack on the weakest point. For instance, much has been published in the past two years about the so-called developments in the electrometallurgy of iron and steel. By a sort of natural evolution it has been seen that the processes which have been selected as survival of the numerous attempts have cast on the weakest spot in the present metallurgy of steel. In the manufacture of crucible cast steel the cost of fuel, cost of crucibles and high labor charge per ton of output makes an expensive product. This expensive product binds the market solely and simply because of its purity, which fills special uses. With crucible cast steel quality is the desideratum. It is self-evident from the nature of electric heating that large units, durable furnaces, low charge of labor per ton of product, ease of control over the purity of the product, that the fact comes out in bold and prominent relief that here is the first chance for a marked victory of the electrical method over the old style of metallurgy.

The second point which should be brought out is that not only should the present status of the old process be known but also a keen forecast should be made as to what improvements the old process is susceptible of. Mr. Johnson referred to an article in our last issue on the manufacture of sulphuric acid by the contact process. There the anonymous writer showed that under the stimulus of competition from the new contact process, the old process has been improved greatly, as regards consumption of nitre and pounds of acid made per cubic foot of chamber space. A meek and timid man will make a good fight if pushed to a corner. So capital will spend thousands of dollars in making changes in plant and process, if it is seen that the life of the company is threatened. Where suggestions as to improvements from the technical force were thought by the head office, to say the least, in distinctly bad taste, in times of complacent prosperity, it is soon seen in the period of war that new ideas and reforms are quite welcome.

Mr. Johnson emphasized that any new process should have a good margin over any possible future cost of production of the old process. The most successful nations have "a preference as a race for fighting ten to one." So, too, with applied electrochemistry, the battle should be fought along the line of least resistance.

It is a truism to remark that any electrochemical process is doubly strong if it combines the best part of the old metallurgy with something new of its own. A principle of practical metallurgy is that for producing the desired results, two, three, or even many more treatments are made to attain the end results. For instance, in the treatment of copper ores in Montana we have first, very cheap mechanical concentration by water, next smelting in regenerative reverbatory furnaces or the roaster blast furnace treatment to a 50 per cent matte. Next, mesmerizing in the copper converter to blister copper, then refining in the reverbatory refining furnace to set copper, and finally electrolytic refining.

Mr. Johnson classes these metallurgical reactions as roughing reactions, intermediate reactions and finishing reactions, the meaning of the terms being self-evident.

The reason for the fact that we have several reactions quite often is that a reaction will work very cheaply, and without undue loss, if it be not pushed to too far an extreme. It then becomes expensive in operation. Now, for the finishing reaction, for the last part of the work, a more expensive reaction can be used which gives low losses and the pure products. Examples of this principle are seen in every metallurgical works. For instance, in its simplest and boldest form in unloading coal or ore from a barge, 90 to 95 per cent can be removed by

mechanical means. The last five or ten per cent must be unloaded partly by man and wheel-barrow. Again, in the copper work it is not practical to make in the matting process a matte running over 50 per cent, for, with a 60 per cent matte the slags would be so high in copper that they could not be put over the dump. Again, in roasting a pure nickel matte to a dead oxide it is very cheap and easy to reduce the sulphur to half of one per cent in a mechanically operated roasting furnace. It is then good practice to use a special roast in hand reverbatories to bring the sulphur to 0.02 per cent. The last operation is expensive, and would prohibit the process if it were attempted to remove all of the 400 pounds of sulphur in the matte by its means. But it is cheap and efficient for the last ten pounds remaining after the first treatment. The principle can be stated that usually a combination of reactions, each suited for its own duty produces the cheapest metal. This general principle is one which has been, and should always be, applied in an electrochemical proposition. For instance, in the electrolytic refining of copper the electrolytic treatment is the last and finishing reaction. Many attempts have been made to use anodes of matte or ore, but only failure has been met with in these attempts. The anode has always been purer after each failure. Now at the present time the practice is to use an anode of refined copper where silver is the chief purity. In this connection it might be noted that the very low percentages of arsenic and antimony present in blister copper could not be removed in anything like the efficient manner as they are done in the electrolytic treatment. History shows that in electrolytic copper refining the cheapest method has been found to use the prior methods for the roughing reactions, and to put on the finishing touches of the refining in the electrolytic bath.

Mr. Johnson then considered any possible future developments in the electrical treatment of nickel material. The alkaline sulphide treatment is very cheap in making a nickel matte containing about one per cent of copper. To remove the last one per cent of copper by this method is done at a great expense. Just here it is possible to apply an electrical method and cheapen the process. In all probability future developments in the metallurgy of nickel will be along these lines.

Another consideration brought forward by Mr. Johnson, is that it is often good business to push a plant to its maximum capacity with high losses, but with an increased output. For instance, in the zinc business, it might be possible to make a charge of roasted ore and reducing material of such a nature that the losses in smelting are very low. But the result of the improved smelting is soon seen on the cost sheet in the increased cost of producing spelter. The old golden mean must be aimed at, and the charge should be made, not for the satisfaction of the metallurgist, but for the purpose of making cheap metal.

In a case where the electrochemical proposition enters a radically new field, conditions are much changed. New products like carborundum or graphite mean that a market must be worked up by skillful advertising along lines which show that their possibilities are great. The author concludes that the modern view of esthetics is that the test of any object is its efficiency. A thing is considered beautiful by the human mind because it connotes in the human mind the sense of efficiency; by efficiency being meant ability to do its duty well. We have in the vista of the brain a dim idea of this efficiency. So, too, with a metallurgical process. A beautiful process is one that does its work well and cheaply.

Testing the Temperature in Electric Furnaces.

A paper on this subject was presented by Mr. Francis A. J. FitzGerald, of Niagara Falls, N. Y. In the absence of the author it was read by Dr. J. W. Richards. The author points out that amorphous carbon, when heated to high temperatures, undergoes various physical and chemical changes. The most important ones are increased density, increased heat conductivity, decreased electric resistivity, increased resistance to oxidation when heated in oxygen, and increased resistance to the disintegrating action of certain solutions.

Mr. FitzGerald points out that by observing the changes which a piece of carbon has undergone while it was subjected to a high temperature, it is possible to estimate this temperature. This is especially useful for studying the temperatures at various points within an electric furnace. The one change which is best suited for such tests is the change in density, and it is this which Mr. FitzGerald proposes to utilize. With very high temperatures amorphous carbon changes to graphite, but even after the change of all amorphous carbon into graphite, there is still an increase in density. A table of densities may therefore be prepared which at the same time indicates the temperatures to which the sample of carbon was heated. The author points out, however, that the density is not simply a function of the temperature alone, but also of the time of heating and of the kind of carbon used.

He then describes the following experiments. A mixture of powdered petroleum coke and pitch was moulded in the form of a rod and baked at a dull red heat for about ten hours. The rod was then broken up and specimens were heated to various temperatures. The densities of the specimens were determined by means of a specific gravity bottle, alcohol being used as the liquid in the bottle, since it wets carbon much more readily than water. A pump was used for removing the air from the pores of the carbon. A series of determinations were made to get a measure of the accuracy of the density determinations, with the result that the percentage average deviation was found to be 0.044. The results are given below, where the densities are those of the carbon at 20° C., compared with water of 4° C.

Specimen.	Temperature.	Density.
1.	Dull redness	1.9141
2.	Above melting point of $CaCl_2$, Below that of Ag.	1.9612
3.	Above melting point of Ag.	1.9853
4.	Above melting point of Cu, below that of cast iron	2.0061
5.	Above melting point of cast iron	2.0363
6.	Heated in platinum crucible over blast-lamp	2.0585

The author gives some results of the application of this method to the study of temperatures in an experimental furnace. The experiments were made by Mr. FitzGerald in conjunction with Mr. P. McN. Bennie. A greater number of samples of carbon were placed at different points in the center and at the ends of a muffle furnace, and it was thus detected that there was a great difference in the temperature in the center and at the ends on account of insufficient heat insulation; the distribution of temperature throughout the furnace was influenced by defective heat insulation. Having detected this, it was easy to correct the design of the furnace. Care should be taken that pure amorphous carbon is used since if impurities like iron, etc., are contained they may volatilize at high temperatures, and may thus produce an apparent change in the density.

Electrolytic Separation of Cobalt and Nickel

The last paper of the session, by Prof. Wilder D. Bancroft, of Cornell University, dealt with this subject. It was presented by the author in brief abstract only, and referred to a method which should be especially useful for the purification of cobalt, as well as of nickel salts by continual electrolysis. The method requires considerable time, but if time is no object, it yields pure cobalt salt or pure nickel salt.

On motion of Prof. C. F. Burgess a vote of thanks was extended to the organization committee of the International Electrical Congress. Prof. Henry S. Carhart referred to the high quality of the papers which had been presented at the different meetings. Then the meeting adjourned.

Papers on Electrochemical and Allied Subjects Before Other Sections of the Congress.

In the following we give notes on papers on electrochemical and allied subjects, presented in other sections of the Congress. The fact that there were such papers is an interesting indication of the steadily increasing influence of electrochemical methods in the other branches of electrical engineering.

Section A.

In Section A three papers were presented on units. Prof. M. Ascoli advocated the "rational" system of Giorgi, by which the factor 4π is eliminated from various formulas, while the present accepted "practical" units are not affected. A paper on the absolute value of the e. m. f. of the Clark cell was contributed by Prof. H. S. Carhart and Prof. G. W. Patterson, Jr.; the results thus far obtained show the e. m. f. at 15° C., to be nearer 1.433 than 1.434. In a paper on "the so-called international electrical units," Dr. F. A. Wolff recommends some action to be taken which will bring about greater uniformity in the units adopted in the various countries. There was an animated discussion in which American and foreign scientists equally participated, the tendency being in general toward conservatism.

Several papers were presented on applications of the electron theory. Prof. C. D. Child gave an explanation of the phenomena of the electric arc on the basis of the electron theory. Prof. J. J. Thomson communicated a paper on "the corpuscular theory," the main part being the experimental proof that the ratio of weight to mass is the same for radium as for other substances. Prof. A. G. Webster contributed a "report on recent developments in electrical theory," dealing with Lorentz's electron theory. Prof. E. Rutherford gave an account of his continued researches on the transition stages of radium. Prof. P. Drude presented a paper on electric conduction in metals, from the standpoint of the electronic theory, Prof. J. S. Townsend a paper on the theory of inization by collision in gases, and Prof. P. Lewis on the electrical conductivity of gases. The latter emphasized that while ions undoubtedly conduct the current through gases, there are very marked differences from the much better understood phenomena in electrolytes. Dr. K. E. Guthe applied the theory of electrons to coberer action.

Prof. H. T. Barnes presented a paper on the mechanical equivalent of heat measured by electrical means. He concludes that the most probable value of the mechanical equivalent of heat, electrically measured, is 4.186 joules in terms of the mean thermal unit which is a mean over the range from 0° to 100° C., and thus independent of any temperature scale.

Section B.

Electrolytic Rectifiers.

A paper on this subject by M. Albert Nodon, of Paris, was read in abstract by Dr. C. P. Steinmetz. The author defines an electrolytic valve as a device, which is able to interrupt the flow of an electric current when it is in one direction, and to permit its free passage when in the other direction. "It consists essentially of a metallic anode of small surface, a cathode of large surface and an electrolyte, which last is generally a salt solution." * * * "The value of the electric charge that may be obtained by means of the valve effect is greater as the molecular weight of the metal which constitutes the anode is smaller. Magnesium and aluminium admit of the valve effect being obtained under a high difference of potential; metals of large atomic weight, such as lead or mercury, on the other hand, produce the valve effect only under a low difference of potential."

"The valve effect may be obtained with ordinary water. In practice, however, the choice of electrolyte is important in the operation of the valves as a result of the more or less destructive nature of the secondary products of the electrolytic reactions. With magnesium, the best results are obtained by means of a saturated solution of alkaline fluorides. With aluminium, the most perfect action is secured by means of neutral ammonium phosphate. The phosphates of potassium and sodium give rise to free potassium and sodium which attack the electrodes and produce an imperfect action of the valves."

The author gives tables showing the results obtained with various metals and electrolytes. Concerning the electrostatic capacity of the valves, he says that he has measured the electrostatic capacity of a valve whose surface had but 0.1 square mm. extent, and which was charged to a difference of potential of 2 volts during a period of less than 0.01 second. The capacity found was from 7 to 10 microfarads." For larger surfaces the capacities are not at all correspondingly larger. "For a given surface the capacity diminishes very rapidly with the time of charge, as a result of the proportional augmentation of the thickness of the film."

The author describes the arrangement and connections for using electrolytic valves for the rectification of alternating currents, and gives results of tests of the wave form.

Section D.

Aluminium for Electrical Conductors.

A paper on this subject was presented by Mr. H. W. Buck, of Niagara Falls. The legitimate uses of aluminium in electrical work are for appliances such as bus-bars, high-tension line conductors and low-tension feeders not requiring insulating covering. Whenever insulation is required, the large cross-section required for aluminium for a certain conductivity, would make the cost of the insulation prohibitive. For this reason aluminium is not suited for interior wiring. Aluminium is difficult to solder, probably since there is always a very thin film of oxide on its surface. But aluminium has now passed the experimental stage for use as conductors. The early troubles from breaking at unexpected places have been overcome in the present stranded conductor. It is durable, except when exposed to sea fog and to atmospheres filled with chemical fumes, and the wire can be given a weatherproof covering in such neighborhoods. The trouble from sleet seems to be less with aluminium than with copper conductors. It costs less to transport and string than copper because it is lighter. When stringing in rough country, however, more care is necessary than with copper to avoid abrasion of the soft aluminium conductors. Soldering aluminium joints has not been found necessary. The author gave the results of tests of the wind pressure on spans. It is proportional to the square of the velocity of the wind.

In the discussion of the paper, Mr. P. N. Nunn questioned whether in actual practice the deflection of aluminium spans under highest temperatures is more than copper, because aluminium is usually strung so that it has enough less deflection than copper in the coldest weather to make the deflection not in excess of copper at the highest temperatures. Aluminium conductors are most apt to be broken by arcs. In the five years' experience that the Telluride Power Transmission Company had with aluminium on lines in Utah and Montana, he remembered but one break not due to an arc. Mr. C. W. Hutton said that in crossing valleys the California Gas & Electric Company had been trying long spans. There was one 1,800-foot span of aluminium cable. There was no trouble from crossing of wires in the wind as all conductors would swing in unison.

Section E.

Mr. Arthur Wright communicated a paper on recent improvements in electrolytic electricity meters. Dr. C. P. Steinmetz presented a paper on the electric arc, pointing out the typical features of the mercury arc and the magnetite arc. Prof. A. Blondel communicated a report on impregnated arc lamp carbons and Mr. H. N. Potter a paper on the development and the characteristics of the Nernst lamp.

Mr. Gerhard Goettling read a paper on storage batteries as an adjunct to central station equipment, discussing the practice of the Edison Companies in the United States. He

pointed out that the battery plates, as now generally used, show great improvements over those of previous years. The positive consists of a rigid conducting support, holding in place soft lead buttons of coiled ribbon with corrugated surfaces, these buttons extending slightly beyond the surface of the grid. The negative plate now consists of a hard metal supporting grid in which the various sections of active material are securely held in place by means of a thin covering of perforated sheet lead. An important development is the substitution of thin wooden diaphragms between the plates as separators in place of the glass tubes heretofore generally used. This new separator effectively prevents any possibility of short circuits forming between the plates, thus keeping the cells in uniform condition, and resulting in a very considerable increase in the life of the plates.

In the discussion of this paper Col. Crompton remarked that the life of a battery is limited by the life of the end cells; for this reason he considers regulation by means of a reversible booster to be preferable to the use of end-cell switches. Mr. J. W. Lieb emphasized that with the present system of generating and transmitting alternating currents to converter substations, storage batteries are absolutely necessary in the latter in order to insure continuous service under all conditions.

Section F.

Mr. J. B. Entz, of Philadelphia, Pa., presented a paper on the application of storage batteries to railway service. He stated that by the use of batteries in railway power stations savings, amounting in cases to 15 or 20 per cent, may be obtained. The positive plates should be of the Planté type, and the negative of the Faure pasted type.

Section H.

Besides various papers in which attempts were made to apply the principles of electrochemistry and physical chemistry to biology and medicine, a paper was presented by Prof. J. W. Langley on the electrolytic purification of drinking water with aluminium electrodes. In a plant in Cleveland, Ohio, the electrolyzer is a rectangular iron box, containing aluminium plates held in grooves in a slate lining, where 500 gallons of lake water per hour are purified, the electric power consumed being 300 watts. Chemical analysis shows the albumenoid ammonia to be reduced upward of 75 per cent and the bacteria from 97 to 99 per cent. In no instant in six months of continuous commercial operation has a single colon bacillus been found, though the lake water generally contains them.

In the following we give an alphabetical list of those who enrolled their names in the register of the American Electrochemical Society: W. D. Bancroft, Ithaca, N. Y.; H. T. Barnes, Montreal, Canada; O. W. Brown, Bloomington, Ind.; William Hand Browne, Richmond Hill, N. Y.; C. F. Burgess, Madison, Wis.; H. S. Carhart, Ann Arbor, Mich.; C. D. Chasteney, Rutherford, N. Y.; H. B. Coho, New York City; F. E. Drake, St. Louis, Mo.; L. H. Flanders, Pittsburg, Pa.; R. E. Fowler; C. Hambuechen, Madison, Wis.; W. J. Hammer, New York City; W. D. Harris, Philadelphia, Pa.; Carl Hering, Philadelphia, Pa.; P. L. T. Héroult, La Praz, France; G. G. Hitchcock; B. H. Hite, Morgantown, W. Va.; G. M. Howard, Philadelphia, Pa.; E. J. Hutchinson, Cincinnati, Ohio; W. McA. Johnson, La Harpe, Kan.; Louis Kahlenberg Madison, Wis.; E. F. Kern, Lansingburg, N. Y.; M. G. Lloyd, Washington, D. C.; H. T. Matthew, New York City; J. T. McNair; C. H. Moritz, Niagara Falls, N. Y.; H. E. Patten, Madison, Wis.; W. G. Patterson, Ann Arbor, Mich.; W. M. Petty, Rutherford, N. J.; A. Pinkerton, Vandergrift, Pa.; Cecil P. Poole, New York City; J. W. Richards, Bethlehem, Pa.; E. F. Roeber, New York City; G. A. Roush; S. S. Sadtler, Philadelphia, Pa.; S. Sheldon, Brooklyn, N. Y.; C. P. Steinmetz, Schenectady, N. Y.; S. Tada; E. R. Taylor, Penn Yan, N. Y.; L. A. Terven, Pittsburg, Pa.; F. J. Tone, Niagara Falls, N. Y.; E. H. Whitlock, Cleveland, Ohio; M. I. Wilbert, Philadelphia, Pa.; H. H. Willard; T. A. Witherspoon, Washington, D. C.; T. Wolcott, Brooklyn, N. Y.; F. A. Wolff, Jr.

NEW YORK MEETING OF THE SOCIETY OF CHEMICAL INDUSTRY.

The twenty-third meeting of the Society of Chemical Industry—the first held in the United States—was called to order by the president, Sir William Ramsay, in the gymnasium of Columbia University on September 8. There were present 700 or 800 persons, and the meeting was probably the most notable one ever held by chemists in the United States. Dr. C. F. Chandler welcomed the meeting on behalf of the University and the New York Section of the Society.

Besides the official business—the presentation of the reports of the secretary and treasurer—the chief feature of the meeting was Sir William Ramsay's address as retiring president, which is given in abstract below. The new president, Dr. William H. Nichols, proposed the vote of thanks to Sir William in a felicitous little speech.

A very pleasant incident was the presentation of the Society's gold medal, founded in 1886, by Sir William Ramsay to Dr. Ira Remsen, of Johns Hopkins. Dr. Remsen answered in a very modest way, saying he wished he could feel he had more fully earned the honor; as it was, if for no other purpose, the medal would serve to "deceive his family" with it.

The Training of Technical Chemists.

In opening his address Sir William Ramsay thanked the New York Section for the hospitable reception. "Gratitude has been defined as a sense of favors to come, and we know that we have reason to be grateful, for you are about to give us, your guests, a token of your regard; you are going to show us your magnificent country, and to demonstrate to us the enormous developments in chemical industry which you have made. We look forward with pleasurable expectancy to the treat which you have in store for us, and we ask you to accept our heartfelt thanks."

After some remarks on previous presidential addresses, Sir William Ramsay proposed to discuss himself some first principles in the training of technical chemists. The education of a chemist (and the word "chemist," of course, includes the qualification "technical chemist") must be conceived in the sense that it consists in an effort to produce an attitude of mind rather than to instill definite knowledge. Of course, the latter must not be neglected. The definite knowledge may be likened to the bricks which the architect has at his disposal in erecting a beautiful building; he knows their shapes, their capacity for resisting stresses, and, in short, what can be done with them. But the conception of the design is the result of many attempts to create; just as the poet has to utilize words, or the architect bricks, so the chemist has to know the materials with which he is dealing. The training of a bricklayer, however, will never make a man an architect; nor will the dry research of a grammarian train a poet. In short, it is the inventive faculty which must be cultivated.

Sir William replied at once to the possible criticism that the inventive faculty must exist and cannot be implanted. He denied it and contended that most of the lads who enter a chemical laboratory are able to receive some inspiration or to have a latent inspiration developed, which will fit them to become inventive chemists.

Now, how can this be brought about? "The answer is perfectly simple: by offering them examples." Every teacher in the laboratory, from senior professor to junior assistant, must be engaged in research, and, most important of all, they must not be reticent, but willing to converse freely on their problems. It is that which creates a "chemical atmosphere." The objection may be raised that junior students are not ripe enough to make any use of such examples. True, and for that reason it is well for the juniors to spend the first year attending lectures and practical classes in rooms for the purpose, and not to let beginners enter the general laboratory. Moreover, they should be attending courses on physics and mathematics, and in the drawing office. But during the second year the initiation should begin. Even during the first

year, the seniors will talk occasionally about what occurs in the main laboratories; the publication of some discovery is sure to be discussed in the junior laboratory, just as the servants' hall discusses the doings of the drawing-room, and the criticism is sure to be somewhat keen, even though—perhaps the more so because it is—founded on insufficient information.

Sir William regards it as a mistake to provide special laboratories for different classes of students. The best instruction a student can get, he obtains in having to explain his operations to his neighbors. A little care makes it possible to assort one's students, so that a shy boy is placed next a kindly senior, and a cocky youngster who thinks he knows everything, is placed next a man who will stand no nonsense, and whose chaff and banter soon dispel the inflated ideas of his own powers which the youngster has brought from his science school. Indeed, the lesson learnt is, that the chief question is not—"What does he know?" but "What has he done?"

The speaker pointed out that there cannot be a greater mistake than to keep a glassblower on the premises. Glass blowing must be learned, since it is an all-important adjunct to the research. "I cannot imagine how any one can stand the annoyance of having to wait for hours, possibly for days, for the repair of a piece of apparatus, which would probably take fewer minutes if the owner was able to manipulate a blow-pipe. Nearly the same may be said of the mechanic's place in the laboratory. Here, however, the work is slower, and in many cases the mechanic's services may be required; but for small repairs, such as soldering, repairing, contriving stirring apparatus, electrical apparatus, etc., much may be done by the student himself without any direct teaching. I confess, however, that a mechanic is necessary, if only to see that the tools are kept in order."

SIR WILLIAM RAMSAY.

After the preliminary year, Sir William does not think it advisable for the student at once to commence research. There are the usual subjects of complex qualitative and simple quantitative analysis to be mastered, the preparation of typical organic and inorganic compounds, besides physico-chemical operations. But the time spent on these may be easily too much extended. A fairly good student should have done enough in a year and a half or two years to place him in such a position that, if necessary, he can help himself when he is face to face with an analysis which he has not made before. When an analysis is regarded as a problem, it gains greatly in interest.

"Above all, not too much teaching. The essence of scientific progress is the well-worn method, trial and failure. It is simply horrible to think of the travesty of teaching in vogue in some of our colleges, where everything is provided, and where the students add one solution to another by word of command, and record their results in special note books constructed for the purpose. What do they learn? To obey? That should have been taught in the nursery. Manipulation? Manipulation consists in constructing what is required, not in using what is given. I had rather see a youth commit the Aeneid to heart than carry out such time-wasting, soul-destroying routine operations. The first may result in a stronger memory; the second is fatal to all originality.

"It may be said that by thus leaving the students very much to themselves, much time is lost. Yes; possibly at first. But the ultimate rate of progress is very much more rapid. Unless the pupil learns to be of use to himself, he cannot possibly be of any use to others. And the training consists in finding out how to do it; not in doing it; that is easy, if one knows how."

The junior staff—the assistants, instructors and lecturers—should not be treated as teaching-machines; they should have at least one-half of their time available for research. Sir William is a firm believer in joint work done by assistants and students. But the number of assistants must necessarily be much greater than the possible vacancies in chairs; here the manufacturers should step in. A member of the junior staff who has done his duty in Sir William's sense, is invaluable if he is not too old, as a works-chemist. If the assistants are to be given leisure for research, the number must be considerable; in a fact, a double staff, in a sense, must be employed.

The speaker then passed over to the senior teachers or professors. He urged that while it is possible to lecture to as many students as the largest lecture room will hold, it is not possible to supervise the practical work of more than, say, forty or fifty students. The reason why the old laboratories of Liebig, of Woehler, and of Bunsen are regarded with such loving memory by those who were the students of these great men is that the total number of students was small; they formed a family party, where the individual character of each was known, and where the father lived among his children, and was able to distribute correction, reproof and instruction in righteousness.

If the reputation of the professor is such that students crowd to his laboratory, Sir William's counsel is, not to build larger laboratories, but to appoint a new professor, with a separate chair, and a new laboratory. "But do not make your man of talent a mere administrator."

It is not necessary that all men of the profession should be highly remunerated; but it is necessary that some should. If they are to teach others, it is greatly to be desired that they themselves should be of the best of their kind. Hence, there should be prizes for the best, comparable in amount with what a successful lawyer, doctor or manufacturer would earn. These prizes should reach the right men. Concerning the method of appointment to chairs he recommends the selection by a committee in which the vacancy occurs, after a reasoned report in which the relative merits of all the possible candidates are discussed. "One is much more particular when one has to choose a fellow teacher with whom one has to pass one's days. It is like choosing a wife. A lady chosen by the vote of the families may prove a success, and no doubt often does. If the wife were chosen in cool blood by the man who is to live with her, after careful inquiry into her antecedents, hereditary and otherwise, her temper, her suitability for the duties which a wife is supposed to perform, there would be fewer unsuccessful marriages. The analogy breaks down; for, unless it is a case of marrying a widow, previous experience should not be a possible consideration. But in selecting to a chair it must."

Sir William then spoke of examinations. "The older I get, the less I believe in University degrees as a test of capacity. Perhaps the reason is the manner in which degrees are awarded in England. The degree follows on one, or at most, two examinations, often by men who know the candidate only as a number, and whose idea of examination often is to set questions to trip the candidate, and not to draw out what he

can do." Sir William emphasizes that a student working under the eye of the professor and of his assistants undergoes a daily examination. He may not earn marks, but none the less, he impresses his teachers with some conception of his character, and the impression is made rather by what he can do than by what he knows.

Under present circumstances, however, as scholarships exist, and must be awarded by examination, it requires considerable ingenuity to devise a method of examination to pick out men who will make a good use of them. "I recently gave as a question for my students, 'Describe shortly the researches which have been going on in this laboratory during the past six months;' and I found the result very satisfactory. The question put a premium on the interest which a student should take in his friend's work, on the intelligence in following it, on his powers of description, and on his suggestiveness where invention had to stand for want of accurate knowledge. The after-effect of such a question, too, will be considerable. The students will endeavor in future to follow the researches of their neighbors with more understanding than they have done."

Concerning lectures, he thinks that students are much overlectured. The object of lectures is more to open out a subject, and to direct a student what to read, than to give definite information. And for that reason I think the senior teacher is the best for junior students.

Sir William thinks that it would be futile to extend courses of lectures to more purely technical subjects. The ideal plan for technical chemists would be some system analogous to apprenticeship of engineers, after they have been educated in the science, that is after the habit of mind has been largely formed.

"I have wondered if it might be possible to establish a training school for technical chemists somewhat on the following lines: To start an association having for its object the encouragement of invention, each member of which would subscribe a certain sum for the erection of buildings and plant. There would need to be a number of isolated buildings, and a considerable collection of stock plant of a small scale—stills, tanks, evaporating pans, filter-presses, vacuum-filters, centrifugal machines, crystallizing vats, and so on. The work shoud be furnished with steam and electric current. Such a syndicate might let it be known that they were willing to make arrangements with inventors, or with syndicates which had secured the patents of an invention, or secured an option on such patents."

However, he thinks that such a scheme would be only an imperfect imitation of the magnificent schools of technical chemistry which form a part of every large German chemical works. Sir William concluded the address with the following words: "It is the scientific curiosity of to-day that often becomes the trade necessity of to-morrow. A scientific friend of mine once drew my attention to the fact that most of the changes which have been introduced in industry have had their origin in the universities. Why? Because the investigator is unfettered. If a man sets himself to improve an existing process, he very likely may succeed, but he will not effect a revolution in manufacture. The purely scientific investigator who is free to follow indications of no apparent commercial import has not infrequently made discoveries of a radical nature, which have entirely changed some particular industry. I do not recommend the one to the exclusion of the other; both are best; and both are best attained by an intimate association between the universities and the chemical works. The investigator often learns much by the study of industrial processes. The chemical manufacturer who is keenly alive to his own interest will not fail to keep himself in touch with every discovery, however little it appears to be connected with his own industry."

* * * *

A report of the proceedings during the days in which the members of the Society of Chemical Industry in New York, as well as of the round trip through the country, will be found on another page of this issue.

— ———

CHAMBER OF DELEGATES, INTERNATIONAL ELECTRICAL CONGRESS, ST. LOUIS, 1904.

The Chamber of Delegates of the International Electrical Congress of St. Louis, 1904, was organized on Monday, September 12, by the election of the following officers: President, Prof. Elihu Thomson; secretary, Dr. A. E. Kennelly; assistant secretary, Dr. F. A. Wolff, Jr., of the National Bureau of Standards.

Two committees were appointed to consider specified questions. The reports of these committees, noted below, were adopted unanimously at the final meeting of the Chamber of Delegates.

The report of the committee on International Electromagnetic Units reads as follows: "It appears from papers laid before the International Electrical Congress, and from the discussion that there are considerable discrepancies between the laws relating to electric units, or their interpretations, in the various countries represented, which, in the opinion of the Chamber, require consideration with a view to securing practical uniformity.

Other questions bearing on nomenclature and the determination of units and standards have also been raised, on which, in the opinion of the Chamber, it is desirable to have international agreement.

The Chamber of Delegates considers that these and similar questions could best be dealth with by an International Commission representing the governments concerned. Such a Commission might in the first instance be appointed by those countries in which legislation on electric units has been adopted, and consist of (say) two members from each country.

Provision should be made for securing the adhesion of other countries prepared to adopt the conclusion of the Commission.

The Chamber of Delegates approves such a plan and requests its members to bring this report before their respective governments.

It is hoped that if the recommendation of the Chamber of Delegates be adopted by the governments represented, the Commission may eventually become a permanent one.

That the delegates report the resolution of the Chamber as to electrical units to their respective governments, and that they be invited to communicate with Dr. S. W. Stratton (Bureau of Standards, Washington, D. C.), and Dr. R. T. Glazebrook (National Physical Laboratory, Bushby House, Richmond, Surrey, England), as to the results of their report, or as to other questions arising out of the resolution."

The committee on International Standardization of Electrical Apparatus and Machinery, recommends "that steps should be taken to secure the co-operation of the technical societies of the world by the appointment of a representative commission to consider the question of the Standardization of the Nomenclature and Ratings of Electrical Apparatus and Machinery." Much of the work should be done by correspondence, in the first instance, a general secretary to preserve the records and to crystallize the points of disagreement. Communications are requested to Col. R. E. B. Crompton, Thriplands, Kensington Court, London, England, and to the president of the American Institute of Electrical Engineers, New York City.

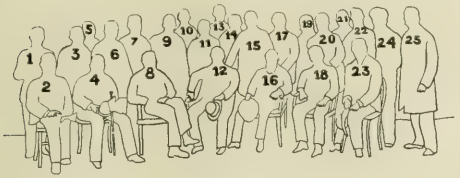
The Chamber included representatives from eleven countries. The Congress was notified of appointments in addition from Austro-Hungary, Mexico and Switzerland, but the representatives from these countries did not appear at St. Louis. Of the five representatives of France, one did not report, and Prof. Henri Poincaré did not arrive until after adjournment of the Chamber.

The group on the following page includes all of the delegates present at the sessions of the Chamber, except Herr Joseph

CHAMBER OF DELEGATES, ST. LOUIS INTERNATIONAL ELECTRICAL CONGRESS.
(See Key on Opposite Page.)

Vater, of Hungary. The accompanying key and following list of names will serve to identify the portraits:

1. Prof. Harris J. Ryan, United States; 2. Herr W. Litzrodt, Germany; 3. Signor A. Maffezzini, Italy; 4. Prof. Dr. Svante Arrhenius, Denmark and Sweden; 5. Dr. F. A. Wolff, Jr., assistant secretary; 6. Herr Bela Gati, Hungary; 7. M. Dennery, France; 8. Dr. R. T. Glazebrook, Great Britain; 9. Or-



KEY TO PORTRAIT ON OPPOSITE PAGE.

mond Higman, Esq., Canada; 10. Dr. A. E. Kennelly, United States, secretary; 11. Senor Miguel Otamendi, Spain; 12 Prof. Elihu Thomson, United States, president; 13. John Hasketh, Esq., Australia; 14. Capt. Ferrie, France; 15. Col. R. E. B. Crompton, C. B., Great Britain; 16. Prof. Moise Ascoli, Italy; 17. Prof. Jorge Newbery, Argentine Republic; 18. M. Zuillebot de Nerville, France; 19. Prof. L. Lombardi, Italy; 20. Marquis Luigi Solari, Italy; 21. Dr. Samuel W. Stratton, United States; 22. Prof. Henry S. Carhart, United States; 23. Senor Antonio Gonzales y Echarte, Spain; 24. Prof. John Perry, Great Britain; 25. J. C. Shields, Esq., India.

COST OF ELECTRIC POWER USED IN ELECTRIC REDUCTION WORKS.

By Louis Simpson.

The article of Dr. Louis Bell, and the paper presented by Mr. P. McN. Bennie before the American Foundry Association, both of which are printed in the August issue of the Electrochemical Industry, emphasize that the question of the possible cost of electrical energy is one of considerable importance for electrochemical works.

Both of these gentlemen admit that the question of producing steel, if not iron, has come within the range of commercial possibilities, dependent more or less upon the prime cost of electric energy. Therefore, it is of importance that such cost shall be ascertained. This can only be done by first ascertaining the cost of purchasing and developing a suitable hydraulic property, and then carefully estimating the several annual charges which go to make up the annual cost for e. h. p.

A firm intended to undertake the business of the electric smelting of iron ores, etc., would naturally seek to purchase a property which would be suitably situated for securing the necessary supplies of the raw material to be used and which would be convenient for the economical distribution of the finished product, but they would chiefly seek to secure a property where electric power could be most cheaply generated. It seems useless to consider the price now asked for e. h. p. by electric power companies. None of these companies were incorporated for the purpose of producing e. h. p. suitable for the requirements of electric ore reduction, nor are their power houses so situated as to meet the peculiar requirements of such an industry.

Dismissing, therefore, from our minds all impressions, received from the methods of electric power companies whose interests and requirements are not in common with the interests and requirements of electric ore reduction, let us examine for ourselves this most important question. The ideal location for an electric power house, the power generated being used for the purposes of electric ore reduction, must conform to the following requirements.

1. The power capable of being developed must be of considerable magnitude, not less than 20,000 e. h. p.

2. The waterfall to be harnessed should possess a head of not less than 40 feet.

3. The head should be able to be made available at a reasonable cost.

4. The conformation of the land should be such that the electric furnaces could be erected immediately adjoining the power house.

Such a location ensures the construction of a power house of considerable size, composed of large units running at medium high speeds. Such a location would in most cases eliminate the necessity for transformers and the need for expensive transmission lines.

Given such location, what would be the cost of the property, hydraulic rights and the necessary development?

Dr. Bell states that such a property would cost from $5 to $25 for each h. p. which could be developed.

Seeing that some of the land will certainly become more or less valuable for purposes other than the production of power, it would appear to be conservative enough to accept $5 per e. h. p. as a sufficient esitmate of cost. The cost of hydraulic development, outside the cost of hydraulic machinery, varies largely in every proposition, but in a favorable location should not cost more than $10 per e. h. p. Should the cost total $20 per e. h. p., the annual rental cost would not be materially increased, because, upon this extra cost, there need be no allowance made for such charges as depreciation, insurance, maintenance or taxes. The cost of turbines, machinery and construction works, which are grouped under this heading, should not exceed $10 per e. h. p.

The cost of electric machinery up to and including the plain switch board necessary would not be more than $15 per e. h. p., unless the peculiar requirements of a process calls for very specially constructed generators.

The cost therefore will be	Per e. h. p.
Property rights, etc.	$5.00
Hydraulic development	10.00
Hydraulic machinery, etc	10.00
Electric equipment including switch board.	15.00
Total cost per e. h. p.	$40.00

Therefore, given a power house in which is generated 20,000 e. h. p., erected at a cost of $40 per e. h. p., what will be the annual cost per e. h. p., the power being used in an ore reduction works erected close to the power house, owned and worked by the same owners and under one management

The power generated is used continuously, extra furnaces being erected, so that, should one need to be shut down for repairs, another is at once placed in commission. The annual cost is made up as follows:

Wages and salaries.
Repairs and maintenance.
Taxes.
Insurance.
Depreciation.

The whole plant being constructed of metal, together with concrete, brick or stone, after the most approved modern fireproof practice, there is little or no risk from damage by fire. The repairs to buildings, etc., will be very small and the depreciation on many portions of the plant nothing.

Wages and Salaries.—The labor required per day will be that of three switch-board men, who, together with two laborers, would take charge inside the power house. On the average, three laborers per day will be required to take care of the outside work. The wages paid these eight men will not exceed, in most cases, $16 per day, or $5,840 per year, equal to 30 cents per e. h. p. There will be no salaries. The management responsible for the reduction work will be responsible for the management of the power house just as in the case of concerns using steam power.

Repairs and Maintenance.—This should not exceed 25 cents for e. h. p. year.

Taxes.—Should the property be in Canada, this charge should not exceed 5 cents per e. h. p. year.

Insurance.—A power house constructed as indicated, requires no insurance. It is advisable, however, to lay aside, to be placed to the credit of a special fund, the sum of $5,000 per year. In case of mishap or disaster the fund would be available. The annual charge per e. h. p. would be 25 cents.

Depreciation.—There is no depreciation upon the value of property purchased, nor upon the excavations made, nor upon the dredging done. Neither should the concrete work depreciate. Turbines when working under a head of water not too high, have been known to be in commission, and in a good state of repair after thirty years of work. In ordinary cases 2½ per cent upon the cost of the turbines will be found to be sufficient. Upon the electrical machinery 7½ per cent should be allowed. The charges for depreciation amount to $1.35 per e. h. p. year.

Summary.

	Per e. h. p. year.
Wages and salaries	$.30
Repairs and maintenance	.25
Taxes	.05
Insurance fund	.25
Depreciation	1.35
Total	$2.20

Were to this added interest (5 per cent) upon the cost of property and construction, the grand total would only amount to $4.20 per e. h. p. year. A calculation of cost of reduction based upon a cost of e. h. p. year at $4.50 may be claimed to be considered as conservative.

But a company owning a large electrical power plant and who intend to use the bulk of the power developed in the smelting of iron ores or in the making of steel, can in all cases find a local market for a proportion of the power generated, and this at prices highly remunerative.

Were 10 per cent of the power generated leased at $15 per e. h. p. year off the switch board, the cost of the power used in the reduction furnaces would be as follows:

100 e. h. p. at $4.20 = $420.
less 10 e. h. p. leased at $15 = $150.
Cost of 90 e. h. p. = $270 or $3.00 per e. h. p.

Were 20 per cent so leased the cost would be
100 e. h. p. at $4.20 = $420,
less 20 e. h. p. at $15 = $300.
Cost of 80 e. h. p. = $120 or $1.50 per e. h. p.

Were 28 per cent of the power generated leased at $15, the annual cost of the remaining 72 per cent would be nothing. Such a result is quite within the bounds of possibility. It will doubtless be contended that e. h. p. has never been generated at $4.50 per year. Such a contention, although perhaps natural, cannot be claimed as being worthy of consideration. "Conditions alter cases." E. h. p. has never yet been developed under the special conditions indicated. Not because those special conditions are not existent or cannot be arranged for, but because industrial conditions have hitherto been such that the special conditions which would permit of the construction of e. h. p. at these low rates have been ignored or have had to give way before the interest of other special industrial conditions. In fact electric power has been generated to meet the requirements of municipal lighting and traction, and of the users of motors rather than the requirements of electric ore reduction. The cost, therefore, has been governed by the special requirements of such users which includes conditions that compel large unproductive (as to power generation) outlays, and also very considerable extra annual expenses.

To complicate matters, the enormous and varying cost of electric transmission has too often been included in the cost of electric power generation making to the outsider "confusion worse confounded." The manufacturer of iron or steel does not seek to secure any profit out of the generation of power. He seeks his profit in the manufacture of iron or steel. If electric power be necessary to his business he seeks to secure it at a cost as low as may be possible. This he can do by arranging (as is possible) to secure the bulk of the capital necessary, to pay for the power development, by the issue of mortgage debenture bonds—power bonds being, and with reason, considered unusually safe securities.

With the capital cost of the power plant so arranged for, the capital required to undertake the construction of an electric reduction plant is very considerably less than that required for a blast furnace plant of the same annual output.

Ottawa, Canada.

Correspondence.

SOLUBILITY OF GOLD.

To the Editor of Electrochemical Industry:

Sir—The prevailing tendency to build up or "develop" a theory by unwarranted inferences seems to me a deplorable one. The theory so "developed" is too often referred to a little later as "established," although these unwarranted inferences are its only foundation.

In this connection I wish to call attention to your editorial in the August number on the "Solubility of Gold" and to the abstract of the paper of Dr. Victor Lenher printed in the same issue. I have not yet received Dr. Lenher's complete paper, but do not believe it could materially alter the case. According to the editorial and the abstract referred to, we are entitled to develop the theory that gold is dissolved or oxidized only by "nascent" oxygen, and incidentally, of course, the theory that there is a nascent oxygen which has properties different from ordinary oxygen.

The reasoning employed in this development is as follows:

1. (This is presumably the major premise.) The experimental facts show that gold is oxidized or dissolved only by very powerful oxidizing agents.

2. (Presumably the minor premise.) Experimental facts show that oxygen is liberated ("oxidized," see literature of oxidation and reduction by O. C. Johnson, E. F. Roeber and J. W. Richards) only by very powerful oxidizing agents.

3. (Conclusion.) Therefore, it is nascent oxygen or oxygen produced simultaneously in a solution which dissolves gold.

This method of reasoning is not at all new in modern scientific research and theory building, but it seems to me a matter which is not according to either recognized principles of logic or common sense.

It seems to me that the only conclusion, or at least the most evident conclusion, from the above premises would be: therefore, reagents which are capable of liberating oxygen are also the reagents which are most likely to dissolve or oxidize gold.

The fact that certain reagents are all capable of producing two independent results, separately observable, is no proof that one result is produced by the other result when both are simultaneous. In this case in particular the evidence in the facts is strong that neither of the two results is produced by the other result; that is, that the gold is not dissolved by the liberated oxygen, and that the oxygen is not liberated by the dissolved gold. Because in all of the reactions cited it is possible to produce either of the two results alone, under circumstances which do not allow the production of the other.

It is now generally recognized by chemists that oxygen can cause the oxidation of other substances only by itself going into combination and never causes oxidation by becoming liberated. There is no known chemical equation or reaction in which an atom of oxygen is liberated, and is at the same time used in producing oxidation. One atom of oxygen may be liberated and another atom of oxygen may be

simultaneously transferred from one substance to another. But there is no evidence that the atom transferred is first liberated. Even of it were, there could not be any evidence of it. The only important inference which can be drawn from the facts, is that the two separately producible results are also simultaneously producible.

This conclusion, instead of causing surprise or being difficult to understand or requiring a theory for its explanation, seems to me the natural and logical result to be expected.

Philadelphia, Pa. C. J. Reed.

[We cannot see the connection between Mr. Reed's communication on nascent oxygen, which is very interesting in itself, and the abstract of Dr. Lenher's paper and our editorial. Both the abstract of Dr. Lenher's paper and the editorial contained simply statements of facts, no attempt being made to "develop" or "establish" a theory. Neither contained the term "nascent oxygen." Our correspondent seems to have been misled by the contents on the front cover of our August issue, where Dr. Lenher's paper was briefly characterized as "an account of an experimental investigation of the solubility of gold under the influence of nascent oxygen." At that place the term nascent oxygen was perfectly justified, since it described (not explained) in few words the facts established by Dr. Lenher, namely, that gold is readily attacked in a large number of reactions in which oxygen is produced; further, that it is necessary for the oxygen to be produced in the mixture, while ordinary oxygen gas, when conducted into sulphuric acid in which gold leaf is suspended will not cause the gold to dissolve.—Ed.]

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By George P. Scholl, Ph. D.

Electric Furnaces and Furnace Products.

Electric Furnace.—C. G. P. De Laval, Stockholm, Sweden. Patent 768,054, August 23, 1904. Application filed May 8, 1903.

The furnace is illustrated in Fig. 1. Its principle is similar to that described in the inventor's earlier patent, 729,614, of June 2, 1903, described in Electrochemical Industry, Vol. I., page 425. Its cross-section shows a furnace chamber 1, with an outlet 3 for gases or metal vapors, a tapping-hole 10 and an inlet 4 for the introduction of the material to be treated. The flat furnace bottom 8 extends from the end wall 7 to the front wall 6, and the electrodes 2 are introduced through the side walls. Cylinders 12, in which the rotating screws 14 are placed, serve to convey the charge from the hopper 13 into the interior of the furnace. It is intended by this construction to feed the material into the furnace in such a manner that it will assume the form of a pile, with a sloping or inclined face a towards the heat focus, the thickness of which pile, in a vertical direction from the hearth, diminishes continuously and is thinnest at the edge of the hearth below the electrodes. It is also intended by means of the flared inlet to have the pile rise somewhat above the inlet, so as to interpose a mass of material between the heat focus and the upper edge of the inlet. The material is fed into the furnace at such a rate as will maintain the slope at such a distance from the heat focus that no sudden development of gases will take place in the material which would be attended by losses on account of the material being thrown about in the furnace. A layer of half-molten material is thus stated to be produced on the surface of the slope and to slowly flow down, while the volatile ingredients which are liberated will escape at the outlet 3. It is preferred to place the outlet opening in such a position in relation to the electric arc, that the volatile ingredients escape directly from the sloping surface into the outlet 3, instead of passing first through the heat focus, in order to avoid raising their temperature. Where zinc ore is the material treated, the metal vapors mixed with the gases pass out at opening 3, while the residuum and the slag are melted by the heat of the arc when in their thinnest layer on the hearth, and are withdrawn through the tapping-hole 10. By reason of the distillation of the zinc and the smelting of the residues taking place in the same furnace, the operation is continuous when the charge is continuously fed in and the slag drawn off. The furnace is intended for the treatment of comminuted materials, such as pulverized ores.

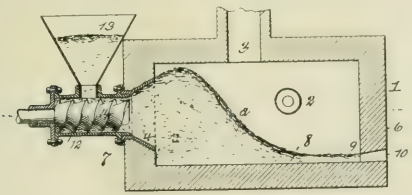


FIG. 1.—ZINC ELECTRIC FURNACE.

Electric Arc Furnace.—A. H. Imbert, Grand-Montrouge, France, Assignor to Société de Métallurgie Eléctrothermique, Paris. Patent 768,995, August 30, 1904. Application filed March 3, 1904.

The furnace consists essentially out of a rectangular chamber, which is connected at both ends with an inclined charging channel. The latter, where they abut into the furnace chamber, are just as wide as the chamber, but become gradually narrower in a vertical direction toward the charging end. The material under treatment is heated by radiation only, by means of arcs sprung between electrodes which enter the furnace through the side walls, and which are automatically advanced and cooled outside of the furnace. The furnace openings, through which the electrodes pass, are also protected by cooling tubes. Experience is said to have shown that it is necessary for the ceiling of the furnace to be as close as possible to the hearth, *i. e.*, as near as the diameter of the electrodes and the avoiding of short circuits will permit, in order to obtain a proper utilization of the heat of the arc. As no material except carbon in the form of graphite will resist under these conditions, an inner arch of graphite is constructed, to form the ceiling of the furnace chamber. As such a graphite ceiling, however, would cause great losses of heat on account of its great heat conductivity and, moreover, would be rapidly destroyed if exposed in an incandescent condition to the action of the air, a second arch of refractory material is built at a certain distance above the first. The space between the two arcs is intended to be filled with inert gases. This method of constructing the furnace chamber in three successive layers—graphitic carbon, inert gases, and refractory materials, is stated to be an important point of the invention. A second important point of the invention is said to be the special combination of the furnace chamber, the

electrodes of the arcs, and the charging channels, the combination being characterized by the shape, the dimensions and the relative situation of the various parts composing the whole. The length of the charging channels should be as great as possible, in order to utilize the heat radiated directly over a maximum heating surface, and to recuperate a large portion of the heat carried off by the gases and vapors issuing from the furnace chamber and rising through the channels in a direction opposite to that of the advancing layer of the charge. The angle of the slope of the channels should be such in each particular case that according to the density and the shape (granular, ovoid, brick-shape) of the charge, the materials to be treated slide along the bottom as the portions nearest to the arc melt, so as to produce continuous and uniform advance of the charge. The two arcs, with which the furnace is provided, are situated near the ends of the furnace in such a position, that about one-half of the heat furnished by each arc strikes directly the walls of the corresponding charging channel and the material under treatment which it contains, while the other half heats the furnace chamber proper. The distance of the two arcs from each other depends on the strength of the current and on the material under treatment, the length being such in any case that the central part of the chamber farthest from the electrodes is maintained sufficiently hot so that the molten materials which accumulate on the hearth may remain at the proper temperature. A tapping-hole and a slag-hole are provided. The gases generated in the furnace escape through chimneys fitted with throttle valves, which serve for the maintenance of a pressure slightly above that of the atmosphere inside of the furnace, in order to prevent air from penetrating into the latter and cooling or burning the electrodes and other carbon parts, or acting unfavorably on the materials under treatment.

Electric Furnace.—Michael R. Conley, New York, assignor to Electric Furnace Co., New York. Patent 769,250, September 6, 1904. Application filed October 1, 1902.

The furnace shown in cross-section in the adjoining Fig. 2 belongs to the resistance type and consists of a receptacle A,

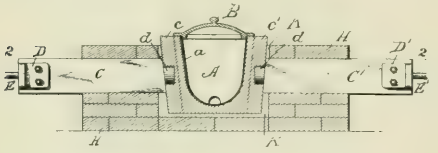


FIG. 2.—CONLEY ELECTRIC FURNACE.

which contains the material to be treated. It may be in the form of a crucible as shown in the figure, or of a cylinder, in which latter case the cylinder rests upon a block of some non-conducting substance as fire brick. The receptacle is made of a mixture of graphite, silica and fire clay, as in an ordinary graphite crucible. It is made under heavy pressure in a mold, and is not spun or turned as the ordinary graphite crucible, inasmuch as the latter method of manufacturing leaves minutes cavities in the finished article. The latter are harmless in the ordinary graphite crucible, but they tend to produce arcs, when an electric current passes through the crucible, whereby large holes are formed which would render the crucible useless. The receptacle is provided with an insulating lining *a*, so as to prevent the current from being short-circuited through the metal or other contents of the receptacle. The insulating lining consists of a composition which becomes plastic when subjected to a high degree of heat and tends therefore to close up any cracks in the receptacle. The material of which this lining is composed is not disclosed. The receptacle is approximately uniform in thickness, and is provided with an extension or wing on each side, which is approximately uniform in cross-section, and reaches from the top to the bottom of the receptacle. Into these extensions the tenons *d d'* of the carbon arms C C' are mortised, for which latter the extensions serve as supports. Their further object is to form conductors which tend to distribute the current vertically and to widen its path, thus preventing a local overheating and the formation of cracks, which would result if the current were allowed to flow in a narrow zone, as it would do if the extensions were omitted. A tight joint between the arms *c c'* and the receptacle is obtained by means of a cement, consisting of graphite and a hydrocarbon such as molasses. This cement is carbonized by the application of heat, with the result that the arms and the receptacle become a practically unbroken path for the current. Metallic plates D D' are bolted to the arms C C', which serve as connection for the leads E E'. The receptacle A and the arms C C' are maintained in proper relation to each other by means of brickwork H. A non-conducting substance K is packed around the receptacle in order to support its walls and to prevent radiation of the heat. Fire clay in a powdered or granulated form has been found to be well adapted in not only preventing radiation, but also in preventing arcing, as when an arc starts in the furnace wall, the comminuted fire clay falls into the place eaten out by the arc and sticks close to the furnace. It is stated to have been found that if the material of the furnace has only sufficient conducting matter to cause the current to start through it when the furnace becomes hot, the current will continue to traverse and heat it, even though the conducting matter is burned out. A diagrammatic arrangement which is stated to be well adapted to practical use shows the furnace connected in the secondary circuit of a step-down transformer, a variable choke coil being included in the primary circuit for controlling purposes. Furthermore, only a portion of the receptacle may be of conducting material, while the rest may consist of a non-conducting substance.

Storage Batteries.

Method of Rendering Storage Battery Gases Non-Explosive.—Thomas A. Edison, Llewellyn Park, N. J., assignor to Edison Storage Battery Co. Patent 767,554, August 16, 1904. Original application filed November 28, 1902. Divided and refiled June 13, 1904.

Fig. 3 illustrates a section view of one of Mr. Edison's improved storage battery cans provided with an arrangement

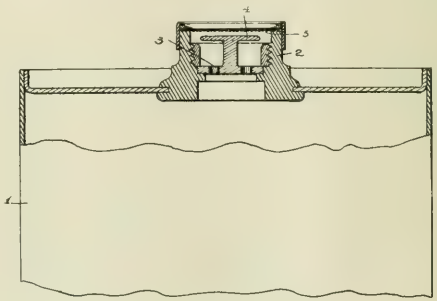


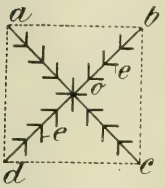
FIG. 3.—EDISON BATTERY.

for rendering the gases non-explosive. The can 1 of thin nickel-plated steel is provided with a neck 2. A perforated plug 3 disposed within this neck carries a deflecting plate 4 for the purpose of diffusing the gases which escape through the perforations. The gases are deflected by the plate and are comparatively attenuated. At the top of the neck there is arranged a suitable cooling medium, as wire gauze, through which the gases escape in a highly rarified condition. Even if they could ignite on the outside of the gauze, the radiating

capacity of the latter is suciently great to prevent its becoming hot enough to ignite the gases below it. No explosion can therefore take place. This is stated to be especially true when the deflector is used, since otherwise there would be danger of a small stream of gas passing directly from each perforation through the gauze in a sufficiently concentrated condition as to result in the gauze being dangerously heated. The method above described can be used in connection with the method of separating entrained globules of liquid, as described in Mr. Edison's patent 764,183, of July 5, 1904, which is described and illustrated in ELECTROCHEMICAL INDUSTRY, Vol. II., page 325.

Electric Accumulator.—Constantin de Sedneff, Paris, France. Patent 768,630, August 30, 1904. Application filed July 28, 1902.

The plates of this accumulator are constructed of a number of elements, one of which is illustrated in Fig. 4. It is composed of two diagonals *a b c d*, from which project branch ribs *e* set at forty-five degrees with regard to the diagonals, *i. e.*, parallel to the sides *ab, bc, cd, da,* respectively, of the square. The paste fills up all the space inclosing the diagonals and ribs. The two diagonals are said to give a contact surface which has 1.41 times the surface of the square frame *abcd*. The ribs, which increase the surface to four times that of the square *abcd*, are set at equal distances from one another and have a uniform degree of projection. The projecting portions of the ribs are equal to their spacing; that is, each rib *e* terminates at a point at right angles or opposite to the root or beginning of the preceding rib, so that the ribs as a whole form a kind of staircase device. Thus, on the increase in volume of the oxide due to peroxidation, the development of considerable mechanical efforts tending to deform the support is prevented. As the expansion moreover takes place in a direction parallel to the ribs *e*, the active matter preserves, in spite of the variations of volume, a permanent contact with the conductive support, and at all points of the latter. The expansion being equal, as the figure is symmetrical around its center *o*, the support cannot undergo any deformation, as the results of the expansive efforts is nil. Instead of having the form of a square, the elements can be of any other geometrical form, *f. i.*, triangular or hexagonal. In all the forms, however, the angular direction of the ribs with regard to the diagonals constitutes a feature of considerable importance, inasmuch as its object is to give the resultant of the mechanical efforts due to the expansion of the oxides such a direction as to prevent any undesirable influence upon the cohesion of the active mass or the contact between the latter and the support. This arrangement is claimed to lead to a considerable improvement in results when compared with those obtained by the majority of large surface plates, as, *f. i.*, those of the Tudor accumulator, in which, if it is built without a core, the expansion takes place perpendicularly to the ribs, which are strongly compressed, while, if the accumulator has a core, the oxide layer is forced back perpendicularly to the ribs, owing to a slight inclination of their faces, and drops. An alternative form of electrode is described in the specification, in which the ribs *e* are continued downwards in a longitudinal direction, so that a prismatic body is formed, of which a figure like the one illustrated would represent a cross-section. This is employed when the battery is intended for a slow charge and rapid discharge or *vice versa*, in order to increase the external surface of either the negative or positive plate. Stress is also laid upon the fact that the weight of the active mass is made equal for both electrodes, and that the proportion between the weight of lead and that of the active mass is the same.



STORAGE BATTERY ELEMENT

GALVANIC ELEMENTS.

Electric Battery.—P. J. Kamperdyk, New York. Patent 768,372, August 23, 1904. Application filed October 14, 1903.

The cell is of the zinc carbon type, the negative pole electrode being a zinc plate, while the positive electrode is composed of groups of small carbon pencils, secured at their ends to metal plates and arranged in parallel rows. The carbon electrodes are placed in porous cups, open at their bottom and held in place by forcing their lower end into a layer of softened asphalt or like material, which covers the bottom of the vessel. Several cups are arranged in each cell. The cups are preferably made of carbon and connected to the positive elements, so as to increase the surface of the electrode. A system of piping connects the interior of all the cups and provision is made for causing the flow of the depolarizing liquid contained in the cups from one to the other. Another system of piping connects the various vessels constituting a battery among themselves, thereby affording a means for an independent circulation of the battery electrolyte, so as to maintain the latter at a uniform density.

Galvanic Battery.—A. J. Jacobson, Hamburg, Germany. Patent 768,180, August 23, 1904. Application filed March 19, 1903.

The cell consists of a cylindrical vessel of zinc or other metal. Within this vessel is placed a carbon electrode of preferably cylindrical or prismatic cross-section. The space between the vessel, which acts as one electrode, and the carbon electrode is filled with blotting paper or similar matrial which is intended to suck up and keep the electrolyte. The cell is closed by a removable lid. It is claimed that the arrangement of a removable cover at one end of the cell affords the great advantage, that such a cell can be kept dry until immediately before its first use, whereby greater efficiency and duration of the cell are secured.

MISCELLANEOUS.

Connector for Electrochemical Apparatus.—O. P. Fritchle, Denver. Patent 768,175, August 23, 1904. Application filed Dec. 28, 1903.

The connector consists of a heavy copper wire sheathed with lead, except at its ends. These ends dip into nickel-plated mercury cups, which are fastened to the electrodes which are to be connected. The ends of the lead sheath on the copper wire are formed into bulbs. A soft rubber sleeve fits closely upon the bulbed ends of the coupler sheath and the mercury cups. This arrangement allows either electrode to vibrate without transmitting the vibrations to the other electrode, the coupler being supported entirely by the rubber sleeve.

Electrical Apparatus for Cleaning Gas.—C. G. Hardie, Hamburg, N. Y. Patent 768,450, August 23, 1904. Application filed November 12, 1903.

The apparatus is intended for cleaning producer, blast furnace and other gases, by precipitating from them the impurities which they contain. The apparatus consists essentially of a long metallic box with an inclined bottom. It is connected with one terminal of a high-potential transformer and is provided with an inlet opening for the introduction of the gases and an outlet. A stream of water runs down over the bottom of the box. Inside of the box there is arranged another electrode in the shape of a flat plate, which is connected to the other transformer terminal. It is insulated from the box by means of glass. It is stated that during the operation of the apparatus, the impurities are thrown towards the bottom of the box and are there caught by the water and washed away.

While the Canadian Copper Co.'s plant is at present operated by steam, the Huronian Co. is to construct a big hydraulic plant at Turbine, Ont., with electric power transmission over 30 miles to Copper Cliff.

SYNOPSIS OF ARTICLES IN OTHER JOURNALS

A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.

Industrial Electrochemistry.

Ozonizers.—The production of ozone by silent discharges through air, and the utilization of ozone for the sterilization of water seems to attract considerable interest at present. Various notes on this subject have been published in our columns. In the London *Electrical Review*, of August 19, J. B. C. Kershaw gives descriptions of various processes of this kind. Fig. 1 is a sectional elevation of the Marmier and Abraham form of ozonizer. A is an air-tight box about 2½ meters in height, containing a number of vertically-placed electrodes, *e e e*. These electrodes are hollow plates of steel, and each carries on its two external faces, plates of glass, *i i i*. The electrodes are placed in the box or chamber A in such a manner that a considerable air space separates each neighboring pair. The air supply takes place by the central channel O, and the arrows in Fig. 1 indicate the direction taken by the air in its passage be-

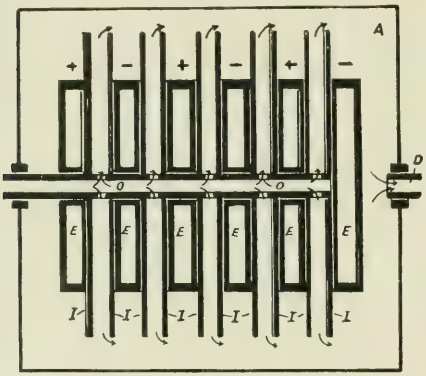
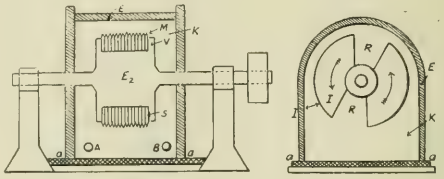


FIG. 1.—MARMIER-ABRAHAM OZONIZER.

tween the electrodes and out of the chamber, by the passage D. The hollow electrodes are cooled by a current of water which flows through them, special arrangements being made to avoid short-circuits through the water supply. Current at 40,000 volts is used for this type of ozonizer, and an external spark-gap is employed to minimize the danger from spark formation in the ozonizer. As regard yield, 1 hp.-hour was stated to produce 20 grams of ozone, and to ozonize 3.4 cubic meters of air at Lille, while at Marseilles an installation in a brewery is said to be producing a concentration of 12 grams of ozone per cubic meter of air, with an initial pressure of 30,000 volts and a discharge equivalent to 5 kw. per square meter of electrode surface. Installations of this ozonizer for water purification are in use at Lille and at Marseilles.

Figs. 2 and 3 are sectional diagrams of Otto's latest form of ozonizer. K is a semi-circular air chamber, with a metal wall, E_1, which forms one electrode. Within this chamber a number of steel discs, *S S S*, are mounted upon a revolving barrel, E_2, the edges of these discs being bevelled, and having the serrated appearance, shown in Fig. 2 at M. Each disc has two segments cut out as indicated at R, R (Fig. 3), and the plate of insulating material (glass), *a, a*, which forms the base of the chamber K, in conjunction with these gaps, effectually destroys any arcs that may strike across the air space, I, I. The air enters the chamber K by B, and passes away at A_1. The rapid rotation of the composite electrode E_2, with its serrated edges, assists in distributing the air through the interior of the ozonizer, before its escape at A. The distance separating the two electrodes should be about 30 mm., and with steel discs 1½ mm. in thickness, having bevelled edges 10 mm. broad, a pressure of 25,000 volts can be employed. The Otto form of ozonizer is employed at one or two factories in France in connection with the manufacture of organic products, and the inventor has recently been carrying



FIGS. 2 AND 3.—OTTO OZONIZER.

out some experiments with it at Niagara Falls in relation to water purification.

The author then deals with the Siemens & Halske ozonizer and the Vosmaer-Lebret ozonizer, which were described at some length in our vol. I., page 179 and 31, respectively. Mr Kershaw concludes the article with the following general remarks. The fact that ozone is formed when the silent electric discharge is allowed to pass through air, or through pure oxygen gas, has been known since the early days of electrical science. The work of recent inventors and experimenters in this field of research, therefore, has been simply directed toward devising forms of apparatus which would be capable of practical application when dealing with large volumes of gas, and toward reducing the losses arising from spark formation and decomposition of the ozone already formed. The methods which have been adopted by different inventors to avoid the danger of spark formation vary greatly. In nearly all the ozonizers glass is used as dielectric between the electrodes. In some, a spark gap is provided in the external circuit, and if the conditions in the ozonizer proper should at times lead to sparking, the main discharge occurs in the external spark gap. Other inventors make use of rotating electrodes, which vary in distance, or in which segmental openings have been made. Should sparking occur with these electrodes, the arc is speedily broken by the increasing distance or by the gaps produced by the rotation of the electrode or electrodes. A third group of inventors use air currents sufficiently rapid to blow out any sparks that may form between the two electrodes, while yet another plan is to use a choking coil in the external circuit, which will not permit the current necessary to maintain an arc to pass into the ozonizer.

Electrometallurgy of Iron and Steel.—Stahl und Eisen of August 15, contains the conclusion of B. Neumann's serial on the use of electric furnace methods in the iron and steel industries. After giving some data on the cost of various processes, he sums up his conclusions. He believes that in the principal iron industry countries, like the United States, Germany and England, which have an abundance of fuel, but only impure iron ores, the electric furnace cannot be expected to become a serious competitor to the blast furnace for the production of pig iron. The conditions are different in countries in which fuel is scarce and where pure iron ores and sufficient water power are available; this is, for instance, the case in South America and New Zealand; in such countries the production of pig iron in electric furnaces may be an economical success. But even in countries like the United States and

Germany the electric furnace may be used advantageously for making high-grade ferro-alloys. He also believes that the electric furnace is capable of replacing the present expensive methods for making crucible steels. Since we will publish a special article on this subject by the same author in one of our next issues, these brief notes must here suffice.

Starch.—In the *Elektrochemische Zeitschrift,* of September, E. Leconte describes an electrolytic starch process which is stated to be in use by the Compagnie Electro-Sucrière in Paris. The rice is first treated three times in sodium hydroxide solutions of decreasing concentration, and is then washed four or five or more times with water each time for several hours. The water is then drawn off and the rice brought to the mill. The dough-like mass, which comes from the mill, is diluted to 4 or 6° Be. and brought on a sieve; a caustic soda solution is added to bring the alkalinity of the "starch milk" to about 1 gram of soda per liter. It is then brought into the electrolyzers which contain vertical electrodes of "aluminium, zinc or any other suitable metal." The electrodes are connected in parallel, but the voltage and current used are not stated. The electrolyzer boxes taper toward the bottom from which the solution is drawn off by pipes, to be brought in very fine sieves, which separate the "organic deposit formed by the action of the current." The starch is collected on inclined surfaces and is stated to be nearly absolutely pure and very white.

Aluminium.—According to a note in *Journal de l'Electrolyse,* August 1, a company has been founded, backed by German Banks and the Italian Society of Electrochemistry, for the utilization of Italian bauxite and the manufacture of aluminium, water power to be utilized in the valley of Pescara.

Magnetic Separation.—The London *Coal and Iron Trades Review,* of July 15, contains an illustrated description of several types of the Wetherill magnetic separator, with an account of the method of working in a German metallurgical plant.

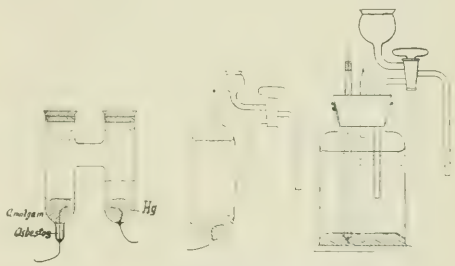
Theoretical and Experimental.

Construction of Standard Cells and Mercury Electrodes.—Of various containing vessels, proposed for standard cells, the H-form has been found most valuable, since in this case the electrolyte always remains saturated in proximity to the electrodes. The ordinary construction, however, with platinum wires fused into the glass has the disadvantage that after some time the vessel cracks on the amalgam side. This is due to the fact that the zinc or cadmium diffuses into the wire which is thus made to expand. Of course, this advantage may be overcome by using a bent capillary tube and passing the wire through it; but the vessel is then very fragile. N. T. M. Winsmore, in *Zeit. f. Elektrochemie,* September 2, describes the following very simple and effective device which is illustrated in Fig. 4. The leg containing the amalgam is provided at its lower end with a narrow continuation which is filled with purified pressed asbestos which prevents the amalgam from reaching the point where the platinum wire is fused into the glass. The author states that the small amount of air remaining in the asbestos is not detrimental; standard cells of this construction maintained their e. m. f. constant for more than a year and a half. Figs. 5 and 6 represent devices for mercury electrodes, which the author has found very suitable. The cock is a three-way cock. H. Danneel describes in the same issue a device by which diffusion of a foreign salt into a standard electrode is prevented by maintaining the connecting siphon under a sufficiently strong hydrostatic pressure.

Mercurous Sulphate in Standard Cells.—In connection with the recent work of Dr. Wolf and Professors Carhart and Hulett, the results of an experimental investigation of the same subject made in the (British) National Physical Laboratory is of interest. The results are embodied in a report of the committee of standards for electrical measurement to the British Association, printed in the London *Electrical Review* of September 9. The work on mercurous sulphate was done by F. E. Smith. Smith has amply confirmed the result of previous investigators that the greater part of the difficulty in obtaining entirely concordant results for the various cells set up by different experimenters is due to the mercurous sulphate. He describes three methods of preparing the paste which lead to identical results, and which have the advantage that cells set up with these pastes have the same e. m. f. within one or two hundred thousandths of a volt immediately after manufacture. In the first method due to Divers and Shiridzu, the paste is prepared by the action of fuming sulphuric acid on mercury; in the second, following Carhart, it is prepared by the electrolysis of weak sulphuric acid and mercurry as anode; while in the third mercurous sulphate is dissolved over a water bath in sulphuric acid. The acid solution is then poured into a large volume of distilled water, and the mercurous sulphate is precipitated in a pure form. In all cases it is important that as advised by Swinburne and Carhart, the salt should be washed, for a Clark cell, with zinc sulphate, and for a cadmium cell with cadmium sulphate, and not with distilled water.

Silver Voltameter.—In connection with K. E. Guthe's Congress paper, abstracted on another page of this issue, an article of the same author in the August number of *Phys. Review* should be of interest. He describes various types of voltameters and their treatment, gives the results of an experimental comparison of the different types, and finally deals with the electrochemical equivalent of silver.

Rotating Cathode for Electrical Work.—A further contribution to this interesting subject is published in the *American Journal of Science,* of September, by H. E. Medway. The author had formerly, in co-operation with Gooch, described a method for the rapid electrolytic precipitation of metals upon a rotating platinum crucible as a cathode. He has now made experiments to see whether platinum may be replaced by cheaper metals. He finds the silver crucible may, with some economy and without sacrifice of accuracy, be substituted for the platinum crucible. On the other hand, in experiments with a nickel crucible, he found that the ease with which the nickel is attacked both during the analytical process and in the subsequent removal of the deposit, is a bar to the use of the metal for a rotating cathode. Shepherd has recommended the use of the ordinary disc anode of platinum as the rotating cathode, in place of the platinum crucible, while a stiff platinum wire, carried in semi-circular conformity to the edge of the disc cathode, serves as the anode. The present author states that with this form and adjustment of apparatus, the deposits obtained are not so adherent as might be desired, and tend to crumble away from the edge of the disc; and the same thing is true of discs of copper and silver. The probable reason for failure to obtain an adherent deposit is that the edge of the disc, being nearer the anode, receives more current and larger deposit of copper than the central portions, with the consequence that the deposit upon the edge, built out and fragile, tends to break off under the rapid rota-



FIGS. 4, 5, 6.—STANDARD CELLS AND MERCURY ELECTRODES.

tion of the disc. To remedy this defect the present author used for an anode a strip of platinum extending across the cell under and parallel to the rotating disc, so that the current may be equalized all over the disc. Very good results were thus obtained in the precipitation of copper. The attempt to substitute aluminium for platinum, was not successful, owing probably to the film of aluminium oxide always present. From his experience he concludes that the disc is inferior to the crucible for use as a rotating cathode.

Carbon Cell.—The full account of the experimental investigation of F. Haber and L. Bruner, which is the subject of their recent Congress paper (see the abstract on another page of this issue) is published in *Zeit. f. Elektrochemie,* September 9.

Ionic Transference Phenomena in Fused Salts.—On the basis of the hypothesis that the conduction of an electric current through an electrolyte is accomplished by cations and anions moving in opposite directions, Hittorf has shown, long ago, that the ratio of the two velocities may be determined by measuring the local concentration changes at the two electrodes. The ratio of the velocity of the cation to the sum of the velocities of cation and anion is called by him the transport number of the cation. These investigations of Hittorf became later the foundation of Kohlrausch's classical researches which lead him to his law of the independent migration of the ions. R. Lorenz and G. Fausti publish in *Zeit. f. Elektrochemie,* August 19, an interesting account of experiments in which they endeavored to determine to transport number in fused salts. They experimented, of course, with mixtures of fused salts, and their first experiments were of a purely qualitative nature. When a fused mixture of equal equivalents of NaCl and KCl with a little $PbCl_2$ was electrolyzed, the cathodic compartment showed a loss of Pb greater than the deposited quantity. When a mixture of much KCl and a little $PbCl_2$ was electrolyzed, the cathodic compartment showed again a loss of Pb while the potassium chloride had increased. The authors then electrolyzed a mixture of equivalent quantities of $PbCl_2$ and KCl and endeavored to determine the transport number of potassium quantitatively at 800° C.; in one experiment they found the value 0.36, in another 0.19.

Thermo Electromotive Force of Nickel Nitrate.—In the August number of *Physical Review,* J. F. Meyer gives the results of measurements of the thermo-electromotive force of nickel nitrate in four different organic solvents. In aniline pyridine with platinum electrodes it is zero through a temperature range of about 80° C. In a solution of nickel nitrate in alcohol the heated electrode is first positive and then becomes negative toward the cold electrode, while in acetone solutions the heated electrode is always positive. The thermo-electromotive force is independent of the concentration from 1/10 to 1/50 normal. The author remarks that polarization effects cannot be avoided and they are large enough to mask the thermal effects in the measurements. He suggests to measure the degree of dissociation in these organic solvents by determining the molecular conductivity. A possible relation between thermo-electromotive force and dissociation might thus be quantitatively shown.

The Constant of the Gas Law.—The *Zeit. f. Elektrochemie,* August 19, contains a paper by D. Berthelot, on the most probable value of the constant R in the law for perfect gases $pv = RT$. If v is the volume of one grammolecule of gas, p the pressure in atmospheres at the absolute temperature T on sea level and in the geographical latitude of 45°, then, according to Berthelot, R = 0.08207 with a possible error of about 1/8000. With reference to this paper, W. Nernst gives in the same issue some further figures. From R = 0.08207 [liter × atmosphere × T^{-1}] he derives R = 0.83155 × 10^8 (ergs × T^{-1}) and R= 1.98507 (gramcal. × T^{-1}). The often used formula for calculating electromotive forces (based on Nernst's theory)

$$\text{e. m. f.} = \frac{RT}{n} \ln \frac{C}{c} \text{ becomes then}$$

$$\text{e. m. f.} = \frac{0.86134 \times 10^{-4}}{n} T \ln \frac{C}{c} = \frac{0.00019833}{n} T \log \frac{C}{c} \text{ volts,}$$

where ln means Naperian logarithms (basis e) and log means ordinary logarithms (basis 10).

Batteries.

Auxiliary Electrodes for Measurements.—The e. m. f. of a storage battery gives a general indication of the state of charge or discharge. But in some cases it is important to be able to determine the condition of a single plate, either the peroxide plate or the spongy lead plate. For instance, when a new type of battery is constructed, it is important to balance the two plates, so that the peroxide plate and the spongy lead plate, when discharged, become exhausted simultaneously—not one plate a long time ahead of the other. For such tests it is useful to measure the single potential of each plate against a small auxiliary electrode suspended in the acid; the plate under test and the auxiliary electrode are then connected to a voltmeter. An article, by C. Liagre, on the use of such auxiliary electrodes is published in *L'Eclairage Electrique,* September 10. For practical purposes which do not require utmost accuracy, a small amalgamated zinc rod is sufficient, but an amalgamated cadmium rod is better. With a density of 1.200 of sulphuric acid, the potential of zinc against peroxide of lead is 2.43 volts, cadmium against peroxide of lead 2.19 volts, zinc against spongy lead 0.40 volt, cadmium against spongy lead 0.16 volt. The potential of the zinc or cadmium electrode may vary by a few hundredths of a volt on account of variations of the concentration of zinc sulphate or cadmium sulphate in proximity of the auxiliary electrode. In practice the results obtained with zinc or cadmium are sufficient, and these forms of auxiliary electrode are easily made and used. Other metals, such as copper, iron, nickel, silver, may also be used as auxiliary electrodes, but they have the disadvantage that by their presence in the solution they may cause local discharges of the negative plate. For most exact measurements auxiliary electrodes should be used in which one of the ions of sulphuric acid, either H or SO_4, is active. The author describes the hydrogen electrode and the mercurous sulphate electrode. A very practical auxiliary electrode is a small, spongy lead plate or a small lead peroxide plate which, however, must be well charged, before they are used. The author gives a diagram showing the relation between the potential of the different auxiliary electrodes H, Zn, Cd, Cu, Hg, Pb, PbO_2.

Theory of Lead Accumulator.—Gladstone and Tribe's double sulphate theory of the lead accumulator is now generally accepted and has been confirmed especially by the extended researches of Dolezalek. However, concerning the details of the ionic mechanism, there exists still disagreement as indicated by the different theories of Elbs, LeBlanc and Liebenow. *L'Eclairage Electrique,* September 3, P. Bary proposes a new hypothesis, the essential point of which is that lead sulphate in solution, under the action of the current, gives peroxide at one side, and spongy lead at the other side after the fashion of all soluble lead salts.

Storage Batteries for Traction.—In London *Electrical Review,* September 9, W. N. Stewart proposes the uses of storage batteries on trains for long-distance electric railways. He wants to employ on a heavy train two sets of motors; one set—for instance, single-phase motors—being supplied from the transmission line; the other set—direct-current motors—from a storage battery on the train itself. The single-phase motors are kept in continuous operation, irrespective of the contour of the line, while the direct-current motors would assist the former only in starting and on upward gradients, while they are used as generators to return current to the battery on downward gradients and in braking, by means of a regenera-

tive system. He claims that the first cost of installation and operating expenses would be smaller for such a mixed system than for a pure single-phase system. From statistics of lines in Italy, where batteries were used on trains, it appears that they were operated nearly 30 per cent cheaper than similar lines using steam locomotives; but the cost of looking after these batteries, exclusive of the cost of renewal plates, was practically as great as the total cost of charging current. The author pins his faith on the Edison cell, which will practically need no skilled attendance and which shows no deterioration.

Miscellaneous.

Magnetic Alloys Composed of Non-Magnetic Metals.—The *London Electrician*, August 26, contains some notes on a British Association paper by R. A. Hadfield, describing the alloys discovered by Heusler, which, though composed of the non-magnetic metals copper, manganese and aluminium, possess considerable magnetic powers. The best results with a given percentage of manganese are obtained when the percentage of aluminium is roughly one-half that of the manganese—*i. e.*, with one atom of aluminium to one of manganese. An alloy exhibited contained 60 per cent copper, 26 per cent manganese and 14 per cent aluminium, and was magnetically nearly equal to cast iron. Unfortunately, it is very brittle and all attempts to draw or forge it have failed. In the discussion which followed it was mentioned that non-magnetic alloys containing as much as 88 per cent of iron had been produced and that a certain amount of aluminium increases the magnetizability of iron. Glazebrook asked whether cooling curves had been taken and suggested that manganese may be magnetic at exceedingly low temperatures, and that the copper and aluminium alloyed with it may raise the temperature at which the magnetism disappears. Hadfield said that adding iron to this alloy would give it the character of a manganese steel and, therefore, make it non-magnetic. This implies, paradoxically enough, that iron may be added to a magnetic metal so as to abolish its magnetic properties.

Special Steel.—A paper of Metcalf, read before the American Society for Testing Materials and published in the August number of the *Iron and Steel Magazine*, gives an outline of our present knowledge of this subject. The analyses of two kinds of high-speed steels are as follows: A tungsten steel contained tungsten 9.99 per cent, chromium 2.83, carbon 0.60, phosphorus 0.10, sulphur 0.10, silicon and manganese traces; a molybdenum steel contained molybdenum 9.65 per cent, carbon 0.65, phosphorus 0.016, silicon 0.046 and manganese 0.22.

On account of limitations of space a number of abstracts had to be reserved for our next issue.

RECENT METALLURGICAL PATENTS.

Gold.

The cyanide process has long been known to have its limitations. For instance, when refractory ores, such as tellurides, are treated with a cyanide solution, the extraction is imperfect. H. R. Cassel (U. S. patent 769,938, September 13) proposes to add bromide of potassium to the cyanide solution and introduce chlorine gas into it slowly and gradually. The gold will thereby be rapidly dissolved, the reactions being stated to be as follows:

$$Cl + KBr = KCl + Br$$
$$Br_2 + 4KCN + 2Au = 2KAu(CN)_2 + 2KBr$$

H. S. Stark (769,280, September 6) patents a process for the extraction of gold from pyritic auriferous ores which is stated to be particularly applicable to the recovery of gold from the residues resulting from the treatment of such ores by ordinary cyanide solutions. The method consists of treating the previously crushed ore with a solution of sulfocyanide of an alkali metal in the presence of an oxidizing agent, including atmospheric oxygen. This latter, assisted by the inherent acidity of the ore, brings about a slow decomposition of a portion of the sulfocyanide, resulting in the production in close proximity to the gold particles of nascent cyanogen and hydrocyanic acid. Both of these substances are powerful gold solvents, and thus upon their formation dissolve out any adjacent metallic gold, which is thereupon carried into the sulfocyanide solution. This solution is subsequently leached out of the ore and its contained gold separated from it by any suitable means.

S. C. C. Currie (769,254, September 6) patents a process of treating sulphurets by a step-by-step method. The ore is crushed and may be concentrated. Then in a raw state it is subjected to the action of steam or heated hydrogen gas, whereby sulfureted-hydrogen gas is thrown off which is stored for further use. The ore is then roasted in a suitable furnace. While still hot, it is then immersed in a hot caustic alkaline solution, such as caustic potash or caustic soda, whereby many of the soluble substances such as the salts or oxides of lead, zinc or other base metals are dissolved. The alkaline solution is then thrown off into a separate tank and sulfureted-hydrogen is passed through it, whereby the base metals are precipitated. The ore from which the alkaline solution has been withdrawn is washed with water and is then ready for treatment by chemical agents for extracting the precious metals. "If a chlorine solution is used, the same may be obtained by the electrolytic decomposition of sodium chloride, and the same decomposition will produce caustic soda, an alkaline agent herein referred to, and hydrogen gas, also before referred to. The gases driven off from the ore in roasting may be mixed and used to form the sulfureted hydrogen referred to as a reviving agent for the caustic alkaline solution. Sulfureted hydrogen is also used to good advantage in many instances in precipitating gold and other metals from the chlorine solution."

Aluminium.

A very peculiar process for making aluminium without the use of the electric current is patented by W. Ruebel (770,389, September 20). "For carrying the process into effect clay is used, which must be as pure as possible—that is to say, which must consist as much as possible of aluminium silicate. The clay is at first made red-hot at a temperature of about 1800° Celsius, then ground and mixed with a sulphur containing compound of calcium, such as gypsum or the like, or with a mixture by means of which such a compound is produced—such as, for instance, a mixture of phosphate of calcium (or a substance containing phosphate of calcium) and sulphuric acid. To this mixture a substance is added effecting the exclusion of the air from the surface of the mixture and containing carbon—such as, for instance, mineral oil, coal dust, waste mineral oil (residuum) or other similar substances. The mixture is put into a crucible or retort and is exposed to a temperature of between 1000° and 2000° Centigrade after the air has been excluded, which may be done, for instance, by covering the mixture with coal-dust, by a reducing flame, or the like. The time during which the mixture is exposed to the high temperature depends upon the quantity of the mixture and amounts to about one-half to two hours. After congealing the contents of the crucible or retort consists of two layers. At the bottom of the crucible or retort is molten metal, and this is covered by a layer of slags, which slags

are mostly not molten together, but are powdery. The aluminium metal so obtained contains sometimes more or less phosphates and sometimes also silicate taken up from the walls of the crucible. In order to obtain a very pure aluminium, it is smelted again with lime, or lime is immediately added to the mixture while still in the molten condition."

The reactions are claimed to be as follows: Aluminium silicate and calcium sulphide react to form aluminium sulphide and calcium silicate. This reaction is accelerated in the presence of phosphoric acid. Aluminium sulphide combines with carbon according to the equation $2Al_2S_3 + 3C = 4Al + 3CS_2$.

Iron and Steel.

In carrying on the basic open-hearth process of making steel it is usual to increase the basicity of the slag in order that it may more effectively remove some of the impurities from the metal, by adding lime or limestone to the bath. When, however, a certain amount of lime has been added, the slag becomes too thick, and if it is then desired to add more lime it has been necessary to use considerable fluorspar in order to increase the fluidity of the slag and to allow of more lime being used. H. Carlsson (768,265, August 23) patents a modification of this process in so far as suitable quantities of titaniferous iron ore are added in the basic open-hearth furnace. This addition, on account of the titanic acid present, makes the slag much thinner and thus serves the purpose for which fluorspar has previously been used. Moreover, the iron oxide of the ore acts to some extent upon the carbon in the bath to reduce the carbon contents of the same. The author believes that the higher the percentage of titanic acid in the ore, the better it is for his process.

J. B. de Alzugaray (768,551, 768,552, 768,553, August 23) patents the following process in which the ore and the materials to be mixed with it are first pulverized and then made into bricks or slabs. The main point of his process is stated to be that he mixes the puverized ore not only with reducing and fluxing materials, but also with a refining agent. His bricks are called "carburized," if, besides the ore and refining material they contain carbonaceous material. They are called "non-carburized" if the carbonaceous material is left out. In the second case the carbonaceous material is added to the blast furnace in the usual way. In the latter case the reducing material employed may be gas. He gives the following two formulæ of the constitution of his bricks:

Carburized Bricks.		Non-Carburized Bricks.	
Ore	65 parts	Ore	65 parts
Coke	25 parts	Fluorspar	5 parts
Fluorspar	5 parts	Sodium chloride	2½ parts
Sodium chloride	2½ parts	Silicate or slag	25 parts
Lime	2½ parts	Lime	2½ parts

The author claims that by thus mixing and treating the ore, the elimination of phosphorus, sulphur and other injurious elements is effected. By the treatment of the bricks carburized and non-carburized separately, he contends that he produces a very high quality of pig-iron which he designates as "refined" pig-iron. By using the two kinds of bricks together or consecutively in the furnace, he claims to have a new process for producing steel. For producing ferro-alloys he mixes the bricks with the oxides of the metals to be added.

Roasting Furnace.

Roasting furnaces of the McDougall type are so constructed that in a cylindrical steel or iron shell which is lined with bricks roasting shelves are arranged one above the other, through the center of which a hollow shaft is inserted. To this shaft rakes or stirring arms are attached corresponding to the different shelves, by means of which the ore is not only stirred, but also moved so that it gradually drops from one shelf to the other until it is automatically discharged from the last shelf. Ottokar Hofmann (768,748, August 30) describes modifications of this furnace, the object being to provide for good cooling of the central shaft, for an efficient cooling of the stirring-arms, and to construct the attachment of the stirring-arms to the central shaft in such a way as to permit a quick and easy withdrawing and replacing of a defective arm.

The furnace, as shown in vertical section in Fig. 1, is arranged for roasting ores like zinc-blende, which require additional heat for completing the roast, and is therefore provided with more roasting shelves *A A A* than are usually found in a furnace of this type, of which the three lower

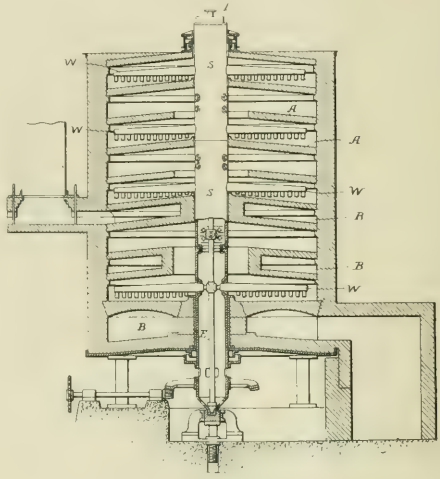


FIG. 1.—ROASTING FURNACE.

ones can receive additional heat by the three inserted fire-flue chambers *B B B*. The central hollow shaft *S* is provided with a number of recesses, two of which always correspond in their vertical location with the location of one of the roasting-shelves. They are placed diametrically opposite and serve for the insertion of stirring-arms *W*. Their position, however, in relation to the different roasting shelves is so that the arms in every succeeding shelf are horizontally at right angles with the arms of the preceding one, so that the ore dropping from one shelf to the other does not strike the rake. Mechanical details of construction are described by which it is easy to insert the arms *W* into the shaft *S*, a kind of "bayonet joint" being applied.

In the center of the hollow shaft *S* is inserted an iron pipe *E* (Fig. 2, which is of larger size than Fig. 1), which is provided with pipe fittings which permit the connections of small pipes *F* with the vertical pipe *E*. These connections are so arranged that the pipes *F* project out into the furnace through the center of each two opposite recesses. The foot end of the vertical pipe *E* is closed and provided with a square iron block. At the top the pipe *E* is connected with a stationary pipe *I* which in turn is connected with the air-pipe of a blower. Near the foot outside the furnace the hollow shaft is provided with openings. To start the operation, the starting arms are slipped over the pipes *F*, inserted in the recesses in the hollow shaft *S*. Then the blower is started. The air is forced through the branch pipes *F* into the starting arms at the furtherest ends, returns through the full length of the arms and leaves them to enter the hollow shaft where it unites with the upward current of air, which enters at the foot of the shaft through the openings provided there. By this arrangement an efficient cooling of the starting arms, as well as of the central shaft, is obtained. The hollow shaft *S* is constructed in three pieces, so as to facilitate repairs.

Apparatus for Wet Process.

C. H. Webb (768,319, August 23) describes a filtering apparatus consisting of a cylindrical vat which can be revolved. Within the vat a grating is formed of strips of wood which are placed diagonally across each other and secured to the internal surface of the vat at an angle to the axis of the barrel so that spaces are left between the strips of each layer. Over the gratings thus formed, a cocoanut matting is fastened. The same arrangement of grating and filtering cloth is provided at the ends of the barrel. The filter cloth may be protected by a layer of sand, spread thereon and kept in place by means of wire gauze. The ore is charged into the vat and the solution is run into it. The vat is then revolved while air is forced through the vat to accelerate the solution. Then, by turning a cock a difference of pressure is set up at both sides of the filtering cloth, so that the ores or slimes are drawn toward the cloth and become built up in successive layers upon the cloth. After the liquid has been withdrawn the residue is claimed to be comparatively dry.

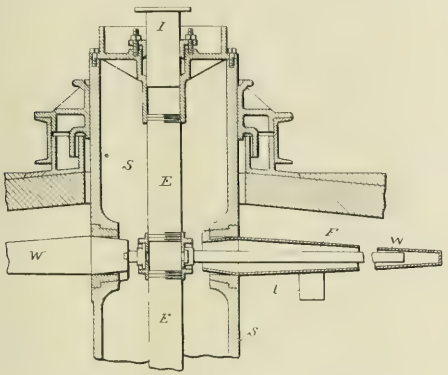


FIG. 2.—DETAILS OF ROASTING FURNACE.

L. S. Turner (768,094, August 23) patents a filtering apparatus for continuously separating metals from pulverulent ores. The essential features consist in making the filter-floor in the form of a ring or annulus, whereby an endless floor is obtained, and in moving this annular floor continuously above a correspondingly-shaped stational trough, which is divided into chambers that are alternately vacuum and compression chambers, air-tight joints being maintained at the edges of the trough, so that the material on the floor may be alternately subjected to the action of suction and blast as it passes above the different trough-chambers.

A. A. Stewart (770,332, September 20) patents an automatic valve for use in connection with leaching tanks, by means of which cyanide solutions, air, lime, gases and the like may be conveniently and uniformally distributed through the contents of the tank.

On account of limitations of space, a number of notes on patents had to be reserved for our next issue.

Germany's Chemical Industries.—According to a recent consular report, Germany's chemical industries have in 1903 worked as profitably as in former years. Some of the largest joint-stock companies declared from 24 to 26 per cent dividends on their share capital, besides carrying heavy amounts of their earnings to reserves and liberally writing off on their real estate and manufacturing plant. In the manufacture of dyes the German chemical works have almost a monopoly, supplying, as they do, their industrial competitors. The same may be said of synthetic indigo, which at this day already supplies more than one-half of the world's entire use.

Book Reviews.

Quantitative Chemical Analysis by Electrolysis.—By Prof. A. Classen. Fourth English from the fourth German edition, revised and enlarged by B. Boltwood. New York: John Wiley & Sons; 315 pages. Price $3.00.

The present edition, as pointed out by Dr. Boltwood, has been published with a view to include much new material, which has appeared since the fourth German edition, in 1897, of Prof. Classen's well-known book. The latter's recent work on "Ausgewählte Methoden der Analytischen Chemie" has therefore freely been drawn upon by the translator, and the arrangement of the present volume differs considerably from that of the fourth German edition on which it is based.

The treatment of the matters dealt with in the introductory chapters, viz., theory of solution, electrolytes, migration of ions, conductivity of solutions, etc., is based entirely on the dissociation theory. The wisdom of introducing the latter subject into a book, which is presumably devoted to practical analytical work, is seriously questioned, and it has been shown by Dr. E. F. Smith's well-known book on the same subject that an exhaustion treatment is very well possible without reference to any particular theory. It seems to the reviewer that the introductory chapter, instead of being amplified by the translator, might have been curtailed and the matter treated from a less, one might say, biased standpoint. The second part of the introduction deals with the measurements of potential and current, the sources of current, as cells, storage batteries, dynamos and thermopiles, and the apparatus for regulating the resistance. It also contains an exhaustive description of the various accessories for electrolysis, *i. e.*, dishes, electrodes, etc. Fourteen pages are devoted to an elaborate description of the former and present equipment of the electrochemical laboratory of the Royal Technical Institute of Technology at Aachen. The latter, with its complicated system of switches, fuses, resistances, etc., due to the employment of only one voltmeter and ammeter for a number of analyses, is decidedly inferior to the system used in this country, where each working place is provided with a set of the instruments, which are kept constantly in circuit while the analysis is going on.

The second part of the book contains the electroanalytical methods for the determination of the various metals, the determination of nitric acid in nitrates, the determination of the halogens, the separation of the metals and the separation of the halogens. Eleven pages are devoted to "some applied examples of electrochemical analysis."

Notwithstanding the above criticisms, the book in its present form is a valuable contribution to the existing literature on electroanalysis, and will well repay investment by anyone interested in the subject.

PYROMETERS SUITABLE FOR METALLURGICAL WORKS.

At the Barrow meeting of the (British) Iron and Steel Institute the suggestion was made that, in view of the growing importance of pyrometers to the steel industry, arrangements should be made to enable members to see the actual working of different pyrometers, in order to enable them to form their own opinions of the relative merits of the appliances available for metallurgical purposes. The council readily adopted this suggestion, and appointed a committee, consisting of Mr. R. A. Hadfield, vice-president, Mr. J. E. Stead, member of council, and Mr. B. H. Brough, secretary, to make the necessary arrangements for the exhibition. In the following we give an abstract of the report of the committee, according to the London *Electrician*.

1. *The Baird and Tatlock Pyrometer* (this description has been prepared by Mr. A. Campion, Cooper's Hill).—This is a

variety of thermo-electric pyrometer in which the e. m. f. developed by the difference in temperature of two similar thermo-electric junctions opposed to one another is measured. The Le Chatelier couple, consisting of a pure platinum wire and a platinum with 10 per cent of rhodium or iridium wire, is used. For use at very high temperatures, the platinum and platinum rhodium couple is preferable on account of its greater durability. The platinum and platinum-iridium couple gives a larger e. m. f., and consequently a more open scale. The measuring instrument is a portable form of high resistance dead-beat D'Arsonval galvanometer, the coil of which carries a long pointer over a graduated scale reading in degrees Centigrade or Fahrenheit direct. A special arrangement is adopted which prevents the pivots of the needle being damaged. In the stationary form of instrument the galvanometer is mounted on gimbals, and is therefore self-levelling. This form of instrument is very convenient when it is necessary to determine temperatures at different points in a large works. In both forms of instruments the moving part is a rectangular coil of fine wire delicately suspended between the poles of a powerful permanent magnet. The magnets, which are made from a special quality of steel, after being magnetized are very carefully tested for dead-beatness and permanency of readings before being made up. The thermo-couple wires are threaded through short lengths of double-bored porelain tubes, which, in turn, are enclosed in an iron or steel outer tube.

The instruments are very carefully calibrated before being sent out. The following is the method adopted: The increments of current furnished by the couple for equal increments of temperature are determined. The current corresponding to the maximum temperature (1,600° C.) which the instrument is to measure being known, a current of, say, 0.01 of the maximum is sent through the galvanometer, and the position of the needle is noted. The current is then increased by small amounts up to the maximum, and the position of the needle noted for each amount. In this way a scale corresponding to equal increments of current, and therefore to equal rises of temperature, is obtained. It then only requires the accurate determination of one point of the scale by a melting point temperature to render it an absolute temperature scale. The calibration of the instruments is not affected by being carried about. Two forms of recording instruments are also made, so that records of temperatures for lengthened periods of time may be obtained.

In the "pyrograph" a band of photographic paper is drawn at a suitable rate under a very fine slit in the dial. The slit is at right-angle to the motion of the paper, so that if the light of an 8-candle-power electric lamp is shining on the dial, some will pass through the slit and blacken the whole band as it is drawn past. The needle, however, of a dead-beat galvanometer actuated by the thermo-electric force of a platinum and platinum-rhodium couple moves above the dial, and this casts a shadow through the slit on the photographic paper, and when this is developed, the record is seen as a white line. The same clockwork which draws the paper also switches off the lamp for one minute every hour, and thus marks white hour lines across the record. A datum line, say at 1,000 deg., is marked on the record by a hair laid across the slit at the point, and by applying a scale to this line on the record the temperature at any part can be ascertained.

In the automatic recorder the needle fixed to a dead-beat galvanometer coil and actuated by a thermo-junction plays between two rubbing contacts. The torsion wire supporting the coil is hung from a differential gear connecting two pieces of clockowrk, and these are controlled by magnets worked by current sent through either of them when the needle completes a circuit through either of the rubbing contacts. The effect is to twist the torsion wire and bring the needle central between the contacts. A lever and pen is also connected to the differential gear, so that the amount of movement needed to bring the needle midway between the contacts is shown and recorded by the pen, which is arranged to write on a drum.

2. *Callendar and Griffith's Thermometers, Thermo-couples, etc.*—In resistance thermometers the increase in resistance of a platinum wire with temperature is observed. The electric-resistance thermometer was first proposed by Sir William Siemens in the Dakerian Lecture in 1871, and it immediately came into general use for metallurgical work. Unfortunately, it was found that small changes in the resistance of the thermometer occurred owing to the chemical action on the platinum of the silica in the porcelain bobbin on which the wire was wound. In 1886 Prof. H. L. Callendar showed that if the platinum is supported on a mica frame, in section, that of a cross with equal arms, there is perfect insulation without any cause of alteration. Prof. Callendar also pointed out the importance of protecting the platinum from noxious gases, all volatile metals attacking platinum readily. The Callendar and Griffith's resistance thermometer consists of a fine platinum wire wound on a mica frame, and connected by means of stout copper or platinum leads to terminals in the head of the thermometer. Two similar leads, but unconnected with the coil, pass through the whole length of the thermometer and act as compensating leads. By this means no error is introduced by the variation of the temperature of the wires connecting the thermometer with the indicator or recorder.

For reading temperature directly by means of a resistance thermometer, the Whipple temperature indicator is generally employed. It consists of a Wheatstone bridge, one arm of which is a long bridge wire wound in the form of a helix on an ebonite drum. A contact maker mounted on the inside of a drum can be rotated over this wire. A scale divided into degrees Centigrade or Fahrenheit is fixed on the outer surface of the drum. The four terminals of the resistance thermometer are connected by means of leads to the indicator, the resistance coil of the thermometer thus forming one arm of the bridge. By turning the handle, the contact maker is moved along the bridge wire until sufficient resistance is introduced to balance the resistance of the thermometer. The galvanometer needle shows the temperature on the scale previously referred to. This instrument has been applied with considerable success to the measurement of the temperature of hardening baths, boiler flues, etc.

On account of limitations of space this description is to be concluded in our next issue.

SUCTION GAS PRODUCERS.

As an economical generation of power is essential for electrochemical industries, it will undoubtedly be of interest to our readers to hear about a new departure in power generation, which makes it possible to generate 1 hp.-hour for ¼ of a cent directly out of anthracite, figuring the latter at $5 per ton.

Producer gas power plants are built for generating out of a suitable fuel a mixture of carbon-monoxide and hydrogen, which, if used in gas engines, allows an exceedingly advantageous utilization of the fuel. Up to the present time producer gas has been produced in so-called pressure gas producers by evaporating water in a separate boiler and by leading the steam, mixed with air, by means of a steam jet blower or fan through the glowing fuel, whereby the steam is decomposed to hydrogen and the coal burned to carbon-monoxide. This mixture of combustible gases is lead through a scrubber to a gas-holder, and from there to the engine. It is evident from this description that for generating gas by this method a boiler and a gas-holder is required, which increases considerably the cost of construction and of attendance.

These pressure gas plants are now being superseded by the so-called suction gas producer plants, which are simpler and

cheaper in construction and easy to attend, since no boiler or gas-holder is required. In a suction gas producer plant the boiler is supplanted by an evaporator, which, in small plants, is built on the top of the producer, and in large plants right near the producer in the form of a tubular evaporator. This evaporator is generating the steam required by utilizing the heat of the producer and of the gases. This is of considerable advantage as compared with the old system, as the firing of a separate boiler is dispensed with, and the heat of the gases produced is used for generating the necessary amount of steam.

The heat of the gases, respectively, of the producer is entirely sufficient for furnishing such a quantity of steam as is required for the generation of an effective power gas. The utilization of the fuel in suction gas-producers is higher than in pressure producers, and is reaching 80 per cent or more. By leading the steam under the grate the latter is kept cool and clean. The transformation of steam into hydrogen and the formation of carbon-monoxide is taking place so quickly that the producer is always making the amount of gas required, and is able to start suddenly from low to full load.

The Working of the Plant.

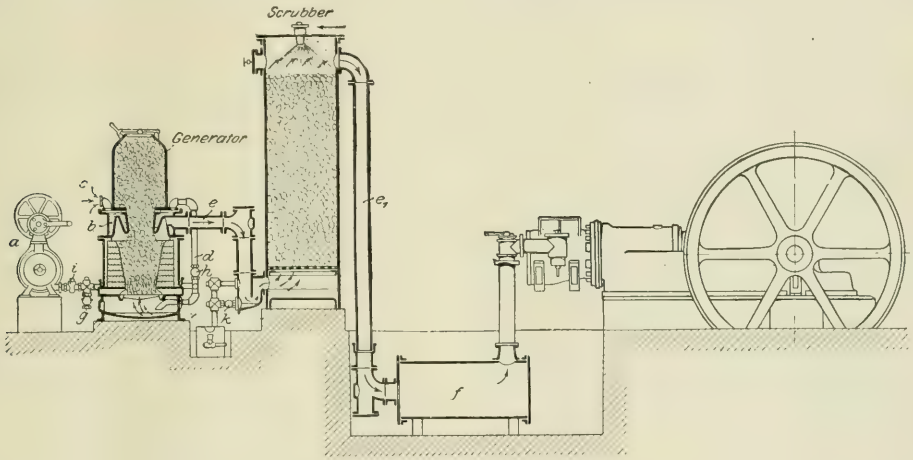
Before starting the engine the fuel in the producer has to be heated up by means of a small blower "a", attached to same, until the gas is burning well. For this about ten minutes are required. When this point is reached the hand blower is stopped and the engine started in the usual way.

The engine is now drawing, by her own sucking action, the necessary amount of air and is producing her own power gas. The air is entering at "c" and goes through the evaporator "b." Here it is saturated with steam and the mixture of air and steam is now going through "d" under the grate of the producer, through the fuel, and then through pipe "e" to the scrubber; from here through pipe "e-1" to the equalizing tank "f", which is directly connected with the engine.

The gas-making process continues as long as the engine is moving, but as soon as the engine is stopped the gas-making is also stopped.

Fuel.

Anthracite, charcoal or coke can be used equally well for generating gas in the suction gas producer. It will take,



SUCTION GAS PRODUCER.

As advantages of suction gas producer plants may be claimed:

1. Automatic generation of the gas by the engine.
2. Highest and best utilization of fuel.
3. No boiler and no gas-holder is required.
4. Can be erected without danger in any convenient place.
5. Easy to start and to run.
6. No soot, no smoke, no odor.
7. No explosion possible.
8. Small floor-space required.

A complete suction gas producer plant consists of a producer, an evaporator, an overflow water-pot, a scrubber and an equalizer (sawdust scrubber). The producer is lined with fire bricks. By the sucking action of the engine a mixture of air and steam is drawn through the burning fuel, whereby the producer gas is generated. There is always only as much gas made as is required by the engine. The producer is provided with a hopper, through which fuel can be filled into the producer without interfering with the working of the engine. The cleaning of the grate may be performed during the regular work. The gas leaving the producer is heating up the evaporator and causes here a formation of steam which goes under the grate together with the necessary amount of air. From the producer the gas goes through the scrubber in which it is cooled and purified from the dust and tar. From the scrubber it goes through a small equalizer.

according to the ash content, 1 to 1 1-3 pounds of anthracite or charcoal, or 1 1-3 to 1½ pounds of coke for developing 1 hp.-hour. With anthracite (pea) at $5 per ton, 1 hp. for twenty-four hours will cost from 6 to 8 cents. This is about one-sixth the cost of illuminating gas power (at a price of 75 cents per 1000 cubic feet of illuminating gas) or one-eighth the cost of gasolene (at a price of 16 cents per gallon).

These plants are built by Oskar Nagel, 90 Wall Street, New York City, in units of from 5 to 300 hp.

INDUSTRIAL NOTES

The Lidgerwood Manufacturing Co., of New York City, have issued a very attractive and fully illustrated catalogue on The Lidgerwood Cableway, a hoisting and conveying device employed in the construction of canals, dry docks, dams, locks, filter beds, piers, log handling, open pit mining, quarrying, discharging vessels, etc.

The Abbe Engineering Co., of New York City, have sent us their illustrated catalogue on pulverizers and pebble mill specialties for fine grinding and thorough mixing. This company has now added a new feature to its business, which is a complete testing laboratory, where they have upwards of a dozen of their different mills constantly set up read to work, when prospective buyers desire the machines do their work before purchasing.

PERSONAL.

Dr. Charles A. Doremus has retired from his duties as professor of chemistry at the College of the City of New York. The last work of Dr. Doremus at the college was to help in the designing of its splendid new chemical and electrochemical laboratory. He will now devote all his time to his duties as consulting chemist in developing and perfecting processes, and as expert in patent causes in chemistry and electrochemistry. Dr. Doremus has always been a strong believer in the future of electrochemical methods in chemistry and metallurgy; he was one of the first advocates and founders of the American Electrochemical Society. His offices will be at 55 West Fifty-Third Street, New York City.

Dr. and Mrs. P. L. T. Heroult, after a trip through the United States and Canada, including a visit to the World's Fair, left for France on October 2. Dr. Héroult presented a highly interesting paper before the International Electrical Congress on the electric furnace in the iron and steel industries. A model of his furnace, and samples of pig iron, special steels and various ferro-alloys, made by his process, are exhibited by the Société Electro-Metallurgique Francaise in the Mines & Metallurgy Building of the World's Fair.

DIGEST OF U. S. PATENTS

Prior to July, 1902.

Compiled by Byrnes & Townsend, Patent Lawyers, National Union Building, Washington, D. C.

Electrolysis of Molten Sodium Salts.

(*Concluded from page 384.*)

623,693, April 25, 1899, Charles E. Acker, East Orange, N. J.

Produces alkali metal hydroxides from alloys of the alkali metal and lead by injecting steam into the molten alloy and continuously removing the product. The apparatus is a cylindrical pot with a central bell extending nearly to its bottom and having a steam inlet. The vessel is closed by a cover, the depending edge of which dips into an annular recess sealed with molten caustic. Steam forced into the bell escapes below its lower edge and rises through the alloy, oxidizing and hydrating the sodium. The caustic accumulates as a molten layer on the metal, and the hydrogen forces its way out through the seal.

679,997, August 6, 1901, George P. Scholl, Philadelphia, Pa.

Electrolyzes a molten mixture of sodium sulphide and caustic soda, equal parts, with a voltage of 1.2. The suphide only is decomposed and the sulphur combines with the caustic, which is replenished. The process is applicable to other metals and other compounds than hydroxide may be added.

Molten Electrolytes, Miscellaneous.

3,698, August 10, 1844, Arthur Wall, Poplar Blackwall, England.

Purifies iron, steel, copper and other metals by passing electricity through them while molten and solidifying. To treat castings, an electrode of clean wrought-iron is embedded in each end of the sand mold, the circuit being closed by the cast metal. One or more iron wires may be stretched through the mold to initially carry the current.

To treat the metal in smelting furnaces or cupolas, iron rod electrodes are inserted in position to touch the molten metal. To treat metal in a puddling furnace, one iron rod electrode is fixed and the other is movable and has a porcelain handle by which it is stirred through the metal. To carburize iron, wrought-iron bars are heated in a bed of animal charcoal, rosin and white arsenic until converted into blister steel, and electricity is passed through them while they are still red-hot and cooling until their temperature falls to a point where they will retain magnetism. The source of electricity is 8 Grove or 20-30 Smee cells.

28,543, May 29, 1860, George Nock, Pittsburg, Pa.

Refers to the desulphurization of coke by electricity.

86,536, February 2, 1869, Alexander Hamar, Philadelphia, Pa

Decarburizes cast iron and converts it into steel by passing electricity through the molten iron as it falls from a ladle carrying one electrode onto a cone carrying the other electrode, and by which the iron is sprayed, a blast of air being simultaneously passed upward through the spray.

86,537, February 2, 1869, Alexander Hamar, Philadelphia, Pa.

Same as preceding.

102,146, April 19, 1870, Charles Motier Nes, York, Pa.

Converts pig iron into steel. A mixture of pig, ore and coals is first smelted in a cupola, steel bars connected to a Grove battery of from 6 to 10 cells being inserted in the hearth in position to pass electricity through the molten iron. The iron is then run into an air-tight fire-brick receptacle, in which it is recarburized and subjected to electricity by wires leading from the battery into the metal. Both the cupola and receptacle are insulated by glass.

104,873, June 28, 1870, Charles M. Nes, York, Pa.

Employs electricity "substantially in the manner described" in the preceding patent to facilitate the conversion of Bessemer steel into cast steel by decarburizing and recarburizing the metal.

108,287, October 11, 1870, Charles M. Nes, York, Pa.

Employs electrodes in forge-fires and converters to improve the quality of the steel, the furnaces being insulated by glass.

133,099, November 19, 1872, A. T. Hay, Burlington, Iowa.

Surrounds the stack of a cupola or blast furnace with magnetizing coils located, *e. g.*, at the "zone of heating," "zone of combustion," "zone of reduction," "zone of fusion," and "zone of carburation."

141,132, July 22, 1873, Octave Gauduin, Jean B. J. Mignon and Stanislas H. Rouart, Paris, France.

Coats iron with copper, gunmetal, "yellow copper," aluminium bronze, etc., with or without the use of electricity. Specifically, electrodeposits from a molten bath of copper chloride or fluoride 1 part, cryolite 5-6, and some barium chloride, the anode being an ingot of copper or a copper containing vessel.

242,397, May 31, 1881, W. L. Thompson, Boston, Mass.

Surrounds the lower part of a stack roaster by an ozonizer and forces air through the ozonizer into the ore to remove sulphur and oxidize base metals.

382,183, May 1, 1888, J. Omholt, Gossnitz, Saxe-Altenburg, Germany.

Electrolyzes haloids of sodium, calcium, strontium, magnesium and aluminium. Separate bodies of the molten electrolyte are held in receptacles in the hearth of a reverberatory furnace. The electrodes are horizontal, parallel bars of carbon or metal, with terminals extending through the masonry. Each electrode is covered with an arched hood and short discharge pipes with their edges slightly above the electrolyte extend down through the hearth into horizontal collecting chambers, which are filled with an inert gas.

390,964, October 9, 1888, A. T. Hay, Burlington, Ia.

Similar to 133,099. The stack furnace is divided into several superposed sections, insulated from each other by a layer of fire clay. Each section is surrounded by a magnetizing coil of copper wire insulated by manila paper and sodium silicate, each coil having an independent battery.

422,500, March 4, 1890, H. Y. Castner, London, England.

Purifies double chlorides of aluminium and sodium or potassium from iron by passing the molten salt successively through several heated trough-like porcelain-lined iron vessels, each containing a series of alternate anodes of carbon and cathodes of aluminum, arranged as baffle plates. The current through successive pots is decreased, to correspond to the decreasing contents of iron

Electrochemical Industry

VOL. II. NEW YORK, NOVEMBER, 1904. NO. 11.

Electrochemical Industry

Published on the first of each month by the
ELECTROCHEMICAL PUBLISHING COMPANY,
[Incorporated.]
114-118 LIBERTY STREET, NEW YORK.

J. W. RICHARDS, PH. D. ..... *President.*
E. F. ROEBER, PH. D. ..... *Editor.*

Telephone Call: 7607 Cortlandt.

Subscription Price: $2 per year, postpaid to any part of the world. Single copies 25 cents.

ADVERTISING RATES GIVEN ON APPLICATION.

Copyrighted, 1904, by the Electrochemical Publishing Co.

Entered as Second-Class Matter, June, 1903, at the Post-Office at New York, N. Y., under the Act of Congress, March 3, 1879.

CONTENTS.

Editorial 435
Refractory Materials for Furnace Lining 435
Film on the Aluminium Anode 436
On the Reality of Atoms and Ions 436
Chemistry at the International Congress of Arts and Science 438
Andrew Carnegie as Bessemer Medalist 438
Refractory Materials for Electrical Resistance Furnaces. By F. A. J. FitzGerald 439
Colloidal Precipitation upon Aluminium Anodes. By William Roy Mott 444
Our Chemical Industries and How to Promote Them 447
The Manufacture of Ferro-Alloys in the Electric Furnace. By Geo. P. Scholl 449
Wilhelm Ostwald 452
Some Examples of Catalytic Action in Electrolysis. By C. J. Thatcher 452
Correspondence: Refractory Materials By E. Kilburn Scott 454
Refractory Materials. By F. A. J. FitzGerald 455
The Education of the Electrochemist 455
Synopsis of Articles in Other Journals 457
Analysis of Current Electrochemical Patents. By Geo. P. Scholl 463
Recent Metallurgical Patents 468
Current Notes 469
Book Reviews: Gray, Electric Influence Machines 470
Electrolytic Production of Phosphate Fertilizers 470
Pyrometers Suitable for Metallurgical Work 471
Lead-Lined Valve in Brass Casing for Handling Acids 472
Dynamos for Electroplating and Electrotyping 472
Industrial Notes 473
Personal 473
Digest U. S. Patents, prior to July, 1902. By Byrnes & Townsend 474

REFRACTORY MATERIALS FOR FURNACE LINING.

In this issue we publish another article of Mr. F. A. J. FitzGerald's serial on electric furnace construction and operation. This article deals with one of the most important practical problems, not only of electrometallurgy, but of metallurgy; namely, to find a satisfactory refractory material for furnace lining. This must be adapted to the special requirements of each case, according to the method of operation of the furnace and the maximum temperature in the same. In every case the refractory material must stand the highest temperature attained in the furnace. Since there is a very wide range of temperature for the different furnace reactions, different refractory materials will be used for different reactions. Another requirement to be fulfilled in every case is that the material is a relatively poor heat conductor so as to reduce to a minimum the losses of heat by conduction and radiation. These requirements must be fulfilled equally well in ordinary metallurgical furnaces as in electric furnaces; the main difference between the two types, with respect to the above requirements, is that the electric furnace is used for reactions which require temperatures beyond the highest attainable in ordinary furnaces. Refractory materials for electric furnaces must therefore be able to stand much higher temperatures than those in ordinary furnaces; they must withstand the reducing action of the carbon in the charge at these high temperatures. For this reason those commercial refractory materials which have proven perfectly suitable in ordinary metallurgical furnaces can no longer be used in electric furnaces requiring the highest temperatures.

There are, however, other differences. As Mr. FitzGerald points out, the conditions are simplified in the electric furnace in so far as there are no troubles experienced in the use of fuel, combined with a powerful blast. On the other hand, the essential nature of the electric furnace introduces a new complication. This is due to the requirement that the refractory material should be as far as possible a non-conductor of electricity. Now, we know, some refractory materials which do not conduct the current at ordinary temperature, become conductors of electricity at very high temperatures; the filament of the Nernst lamp is an example. The problem is, therefore, pretty complicated, and all our readers will certainly appreciate the information given by Mr. FitzGerald on a subject about which very little has been published up to the present. Mr. FitzGerald shows that we have three different materials suitable for refractory materials in electric furnaces. For the lower ranges of temperature we have the series of silico-carbides, for the next higher range carborundum, for the highest temperatures charcoal. Mr. FitzGerald gives a great amount of useful information concerning

methods of employing these materials for furnace linings. He emphasizes the great importance of good heat and electric insulation. Of course, in numerous cases it will be possible to avoid any furnace lining, but methods for this purpose will be dealt with in an article in a coming issue.

THE FILM ON THE ALUMINIUM ANODE.

The extremely high affinity of aluminium for oxygen—indicated by its correspondingly high oxidation heat, and by the very high velocity of the reaction—is the chief reason of the difficulty of the reduction of aluminium. When the purely chemical process had spoken its last word on the manufacture of aluminium, it was necessary to resort to the electric current as the only agent capable of breaking up easily those fixed and difficultly-transformable compounds of strong metals, which are of such large occurrence in nature. The high affinity of aluminium for oxygen also seems one of the chief factors which render the electrolytic precipitation of aluminium from an aqueous solution so very difficult, since any aluminium which may be deposited tends immediately to reoxidize; Dr. Patten's recent, and to some degree successful, attempt to use a solvent containing no oxygen appears to confirm this view. The high affinity of aluminium for oxygen also appears to be responsible for that thin, invisible, yet always present film on an aluminium surface, which, under certain conditions, effectively prevents contact of the aluminium metal with the air, solution or other surrounding medium, wherever no special means are taken to break down the film. The difficulties in soldering aluminium are assumed to be chiefly due to this film. Again the film is active on an aluminium electrode by preventing the electric current to pass in one direction, but allowing it to pass in the other direction—the latter being that in which the current is able to reduce the film. This last property has been utilized in the employment of aluminium electrodes in electrolytic rectifiers and electrolytic condensers.

The nature and the properties of the film on the aluminium anode have been the subject of an extended experimental investigation of Mr. William Roy Mott, who has contributed a series of articles on it to our columns. In an article in our April issue Mr. Mott dealt with the corrosion of aluminium and its prevention; in our July issue with the dimensions of the films on aluminium anodes; in our September issue on the electric properties of the film, its specific resistance, dielectric strength, its specific inductive capacity, and the critical voltage. To our present issue he contributes a highly interesting article on colloidal precipitation upon aluminium anodes. He considers the composition and chemical nature of the film in the light of the general phenomena of colloidal precipitation. Solutions of chromates, phosphates, tartrates, citrates, etc., strongly precipitate colloidal aluminium hydroxide. The same electrolytes produce insulating films upon aluminium anodes. Analyses show that the insulating film consists of aluminium hydrates combined with basic salts of aluminium, or, stating it in another way, the film consists of aluminium oxide, water and acid radical. Aluminium hydroxide is first produced on the aluminium anode, and this reacts with the electrolyte. The loose, incoherent aluminium hydroxide adsorbs the acid radical by its great chemical affinity to form a very hard, dense, insoluble solid which possesses great insulating power—the well-known properties of the film. The necessary thickness of the insulating film varies with different electrolytes. The valence of the acid radical is of decisive importance. Electrolytes containing acid radicals of high valence give high critical voltages and films of great specific resistance and high dielectric strength, and so thinner films are obtained—thus, less coulombs are required for the formation of the film. Mr. Mott's paper appears to give for the first time an explanation of the complex phenomena in the anode film, and since this explanation is also able to predict what to expect from new electrolytes, with respect to the properties of the film, formed on the aluminium anode, Mr. Mott's paper deserves the greatest interest of all interested in this subject which is of equal importance scientifically and practically.

ON THE REALITY OF ATOMS AND IONS.

In an interesting paper presented at the recent International Congress of Arts and Science in St. Louis, on present problems of organic chemistry, Dr. William A. Noyes raised his voice against the strong present tendency on the part of some chemists to claim that chemical science in the true sense includes only such portions of our knowledge as can be stated in accurate mathematical terms. Dr. Noyes considers it impossible to conceive that those theories with regard to structure which have guided the work of thousands of chemists for the last fifty years do not in some measure express the actual truth with regard to atoms and their relation to each other in organic compounds. Dr. Noyes emphasizes as his very firm conviction that we should not be content with rounding out organic chemistry as a descriptive science, nor even with adding to the number of empirical rules which enable us to predict certain classes of phenomena—but that we must, instead, place before ourselves the much higher ideal of gaining a clear insight into the nature of atoms and molecules and of the forces or motions which are the real reasons for the phenomena which we study. Evidently, Dr. Noyes does not consider the conception of the atoms and molecules to belong to those "empirical rules which enable us to predict certain classes of phenomena;" in his opinion, atoms are realities.

Dr. Noyes' note of warning against the exaggerated mathematical tendency in theoretical chemistry is, without doubt, timely, but it is doubtful whether he does not go to the other extreme by proclaiming atoms as realities. Maxwell has once stated the situation of theoretical physics most lucidly as follows: The first object is to simplify and reduce the results of previous investigation to a form in which the mind can grasp them. The results of this simplification may take the form of a purely mathematical formula or of a physical hypothesis. In the first case, says Maxwell, "we entirely lose sight of the phenomena to be explained; and though we may trace out the consequences of given laws, we can never obtain more extended views of the connection of the subject." This

is in fact the danger which confronts those chemists who rigidly follow the mathematical course attacked by Dr. Noyes. On the other hand, to quote again Maxwell, "If we adopt a physical hypothesis we see the phenomena only through a medium, and are liable to that blindness to facts and rashness in assumption which a partial explanation encourages." If these words had not been written in 1855, one might think they refer to some phases of the development of the electrolytic dissociation theory; and it would seem, the danger is the same if we conceive atoms to be realities. What Maxwell advocates in theoretical physics is the development of physical analogies, of mechanical models. An analogy or a model will never be supposed to be the thing itself, but only to represent or illustrate it in those respects for the illustration of which it was devised. There is, then, no danger of making unwarranted generalizations. On the other hand, in the vividness of its conceptions and fertility of its methods, a model is all that can be desired for the purposes of theoretical physics and chemistry; what is needed is a working hypothesis. The conceptions of atoms and ions have proved to be an enormously useful working hypothesis and this fact represents their merit in physical science. Whether atoms or ions really exist, is rather a question of metaphysics.

As long as we bear in mind that a physical or chemical hypothesis or conception represents only a model, we develop the model only to such an extent as is necessary to illustrate those facts which we wish to illustrate. We are not liable to add any imaginary properties to our model beyond those which we need; but this danger at once arises when we forget that a physical conception is only a model, and when we consider it as a reality. Thus, the conception of atoms led the chemists to consider and define them as the smallest possible chemical masses, although there is nothing in the facts of the combining of elements in constant multiple proportions, etc., which would necessitate such a view. Of course, if we accept this definition of the atom, it is true that the development of the electronic theory has brought about an "explosion" not only of the atom, but of the atomic theory. In reality, however, there is nothing contradictory between those properties of the atom which we must attribute to it in order to illustrate the old well-known chemical facts of the combination of elements, and the more recent achievements of the electronic theory. As a matter of fact, the latter may be considered to satisfactorily supplement the old model of the atom in various points in which it was vague. For instance, with respect to valency, the model of a cuprous atom differs from that of the cupric atom, in that the latter contains one more positive electron. Moreover, as J. J. Thomson has shown, we can conceive the atom as a structure of electrons in such a way that we get a complete illustration of the periodic system of elements. The beauty and importance of these models is not diminished in the slightest degree if we keep in mind that we have to do with models only which may or may not represent realities.

The electrolytic dissociation theory has undoubtedly been enormously successful for those purposes for the illustration of which it was originally devised; namely, for the description of the phenomena in dilute aqueous solutions. In this field it has proven to be such a highly valuable working hypothesis that people who confessed to be doubtful as to the reality of atoms, acted as though they were sure of the reality of ions. The properties which had been contributed to ions for the illustration of the facts in dilute aqueous solutions, were at once assumed to explain also the phenomena in more concentrated solutions and in other than aqueous solutions. The fact that there is manifestly a connection between chemical affinity and degree of electrical ionization in aqueous solutions, was generalized into the statement that all instantaneous chemical reactions in any solution take place between ions. Prof. Kahlenberg has shown that a practically instantaneous reaction takes place between hydrochloric acid and copper oleate in a solution in dry benzene, although the solution does not conduct the electric current, and there is no evidence of the dissociation of either the copper oleate or of the hydrochloric acid. He concludes that the above generalization is wrong. Dr. Noyes tries to escape this conclusion by supposing that a substance not already in the form of ions may separate into them under the influence of a second substance with which it can react. This may or may not be so, but it is not clear how such an assumption can have any value as a working hypothesis. It is not a model made to describe facts, but an assumption made to reconcile artificially a generalization which is so far not proven with an established fact which appears to contradict it directly. Prof. Bancroft recently remarked that when one remembers that Goldschmidt has shown the undissociated substances to be the active masses in certain reactions, one wonders why there should be this frantic desire to make all reactions ion reactions; it has not proven itself a useful working hypothesis and therefore, by definition, it is valueless for the present.

We think it was Helmholtz who first proposed the view that chemical affinity is electrical attraction between charged atoms. This scheme has become much more lucid by the development of the electronic theory and by the explanation of valency on the basis of this theory. Of course, if this general theory holds good, all chemical reactions are ionic reactions. This is undoubtedly a beautiful conception; if proven, it would make the whole field of chemistry a single chapter of the electronic theory. If we follow the present general course to explain everything by electrons, we will find it to be either right or wrong, and we will at least arrive at the limitations of the electronic theory. At present we must not forget that the electronic explanation of chemical affinity is so far only an unproven hypothesis. The case is quite similar to that of the mechanical theory of heat which has been predominant for such a long time in the explanation of heat phenomena. In fact, this hypothesis appears to have been so generally accepted that in his first paper on the principle of the conservation of energy, Helmholtz based his first proof on the mechanical theory of heat. In recent years, however, this theory has lost much of its glory, and this example should caution us not to rely too much upon very general hypothetical assumptions which are not directly based on experimental evidence.

CHEMISTRY AT THE INTERNATIONAL CONGRESS OF ARTS AND SCIENCE.

The International Congress of Arts and Science held at the Universal Exposition at St. Louis, from September 19 to 25, was arranged with a view of bringing the scattered sciences and arts into closer mutual relations. This was to be accomplished by papers read by leading representatives of theoretical and applied sciences, in which the general principles and fundamental conceptions which connect groups of sciences should be set forth. The history of special sciences should be reviewed, their mutual relations should be shown and their present problems discussed. In the following a concise abstract of the proceedings of Department 10 (chemistry) shall be given. A report of Section E (technical chemistry) of Department 18 (technology) will be given in our next issue.

In the general meeting of Department (chemistry) the chairman, Prof. J. M. Crafts, pointed out that mathematics is now doing for chemistry what Newton once did for astronomy. Prof. J. U. Nef reported on the decomposition points in alcohol and ether, while Prof. F. W. Clarke spoke on the importance of physical chemistry.

In Section A, devoted to inorganic chemistry (Chairman Prof. J. W. Mallett), Sir William Ramsay delivered an address on molecular weights. He pointed out that all chemical discoveries show an intimate connection with the methods of research. A splendid classification of the elements was given by Lothar Meyer and Mendelejeff in their system of elements. The recent discoveries of radium, polonium, etc., are especially interesting to physicists, while the gases originating from the emanation of radium lead to the new elements of the argon group. It has been found that the chemical compounds of nitrogen show a molecular weight of nitrogen different from that of nitrogen alone. It has also been found that Avogadro's law is not exact. Thus new views are opened for research in the field of moleculiar weights.

Prof. H. Moissan spoke on "Mineral Chemistry in Relation to the Other Sciences." He gave an outline of the different periods of chemistry. First the view was held that the chemical elements are to be found in water, fire, air and earth. After the views on elements had been claered up, the laws of chemistry were investigated by men like Gay Lussac, Richter and others. After the period of establishing laws there followed a period of experimental work. Stas determined the moleculiar weights. Finally mineral chemistry having been developed, organic chemistry was founded. The latter was predominant during the last half of the nineteenth century until at its end new paths were opened for inorganic chemistry. Discoveries like that of Gauthier that arsenic is present in all animal and vegetable organisms show that mineral chemistry plays an important role also in organic life. The speaker concluded with the remark that Faraday's words still hold good to-day that chemistry is an experimental science.

In Section B, devoted to organic chemistry (Chairman Prof. A. B. Prescott) Prof. W. A. Noyes spoke on the present problems of organic chemistry. The successive steps which have lead to our present standpoint in organic chemistry are the discovery of isomerism, the discovery of radicals, the old radical theory, the theory of types, the establishment of true molecular weights, the discovery of the fact of valence and the determination of structure. The object of future researches must not only be to round out organic chemistry as a descriptive science or to add to the number of empirical rules which enable one to predict certain classes of phenomena, but rather to gain a clear insight into the nature of atoms and molecules and of the forces and motions which are the real reason for the chemical phenomena. The author gave a general outline of the applications of the electronic theory to the atomic theory. Prof. J. Stieglitz discussed the formulæ of the speed of certain organic reactions.

In Section C, devoted to physical chemistry (Chairman Prof. Wilder D. Bancroft), Prof. J. H. van't Hoff gave an historical outline of the researches on the nature of mass and on the nature of affinity. His sketch was based on a table containing the names of the investigators in the field of theoretical chemistry. His own name was not mentioned by the speaker, but this omission was made good by Prof. W. Ostwald, who pointed out that the two fields of chemical research which have to do with chemical masses and chemical affinity respectively, were joined by the work of van't Hoff. At the same time Ostwald attacked the atomic theory by pointing out that as a result of the recent researches on radium and of the development of the electronic theory, the atom has "exploded."

In Section D, devoted to physiological chemistry (Chairman Prof. W. O. Atwater), Prof. Sohnheim discussed the food problem, which is on the boundary line of physiology and national economy. Physiology has shown that albumen, fat and hydrocarbons can replace each other for purposes of food, exactly according to their calorimetric values. The only exception is that the daily food of man must contain about 100 grams of albumen. The thermal equivalent of the total amount of daily food varies between 2200 gram calories and 4500 gram calories, according to the work done by the muscles. A man who does not do hard, laborious work must, therefore, consume relatively a greater quantity of albumen in proportion to his total food than a man doing hard, laborious work. This fact is well known and has led to an exaggerated opinion of the importance of albumen in food. If the proportion of albumen in food is too large, the content of cellulose is relatively small and the digestion is not normal. This is the reason why people who do brain work need sports like golf.

Prof. R. H. Chittenden spoke on the present problems of physiological chemistry and especially on those points which lack explanation.

ANDREW CARNEGIE AS BESSEMER MEDALIST.

The annual meeting of the (British) Iron and Steel Institute was held in New York City from October 24 to October 27. It was the second meeting held in this country, the other one having been held fourteen years ago. The first session, on October 24, at Sherry's, was memorable by the presentation to Mr. Andrew Carnegie of the Bessemer gold medal, the presentation speech being made by Sir James Kitson Sir James dwelt at length upon Mr. Carnegie's achievements in the iron and steel industry, and spoke of a visit he made to the Pittsburg steel works many years ago with Mr. Carnegie as his guide, when, in response to a question, Mr. Carnegne confessed that he did not understand the intricate machinery employed in his works, but said he did believe he understood the man who was behind the machinery and running it. Taking this as his test, Sir James spoke of Mr. Carnegie's general attitude toward inventors and others who had been of such vital importance in building up the iron and steel industry.

Mr. Carnegie, accepting the medal, replied somewhat briefly, but with evident feeling, saying among other things that there were several kinds of men—the man who did great things and did not get credit for it, the man who did great things and did get credit for it and the man who got credit for about ten times more than he ever did, and to this last category Mr. Carnegie modestly consigned himself. He did give himself credit, however, for the possession of common sense and quoted the epitaph which several times he has said he wanted placed on his tomb: "Here lies one who knew how to get around him, men cleverer than himself." Mr. Carnegie concluded with the remark that he hoped to hold his medal and pass it on to his descendants as he received it—pure gold and untarnished.

Prior to the presentation of the medal Mr. Fornes, as the representative of the Mayor of New York City, made a speech of formal welcome on behalf of the city, to which Mr. Carnegie, as president of the Institute, replied.

REFRACTORY MATERIALS IN ELECTRICAL RESISTANCE FURNACES.

By F. A. J. FITZGERALD.

In those cases where electrical resistance furnaces are used for relatively low temperature work the problem of finding a satisfactory refractory material is not always more serious than in the case of ordinary furnaces. In some ways the problem is simplified because the troubles experienced in the use of fuel, combined with a powerful blast, are absent. On the other hand, in the electric furnace new problems are encountered; such, for example, as the increased electrical conductivity of the refractory materials when raised to a high temperature, the reducing action of carbon on the compounds of which the refractory material is composed, etc.

When the electric furnace is used for work requiring a very high temperature the problem of obtaining a satisfactory refractory material becomes serious. None of the ordinary refractory materials is satisfactory, and it may be said that no thoroughly suitable refractory material exists. As an illustration of the troubles experienced in the ordinary refractory materials, an experiment in which some Buttersen muffles were used may be described. The muffles were heated by covering their tops and bottoms with a resistance material composed of granular coke, through which a current was passed. Satisfactory results were obtained so long as the temperature of the resistance material was not pushed very high, but when the attempt was made to get a high temperature in the granular coke the muffles were fused as shown in Fig. 1. Examination of the photograph will show that the holes fused in the muffles are surrounded by a mass of granular coke, agglomerated by the fused fire clay. Not only has fusion taken place, but it is found that the material of which the muffles are made has been reduced by the carbon, for many grains of the latter are covered with a light green colored substance that is readily recognized as amorphous silicon carbide. In places, too, there are found metallic particles of a silvery lustre, these being composed of an alloy of silicon and aluminium, produced by the reduction of the constituents of the muffle.

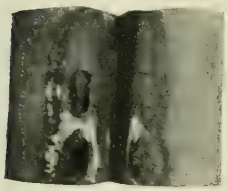


FIG. 1.—HOLES FUSED IN MUFFLES BY TOO HIGH A TEMPERATURE.

It would have been possible to attain the desired object in this experiment without fusing the muffles; but one of the greatest advantages in the use of the electric furnace is the possibility of having the *source of heat* at a very much higher temperature than that required for the work in hand. When heat is conveyed from a source at a temperature T to a substance at a temperature θ, the rate at which the temperature of the latter is raised is a function of $T-\theta$, and the greater the value of $T-\theta$ the more rapidly will the temperature of the substance be raised. As θ increases the value of $T-\theta$ decreases, consequently, the amount of heat conveyed per second from the source to the substance becomes less. Where the source of heat is at a temperature but little higher than that to which it is desired to raise the substance, the attainment of the final temperature takes a long time. Herein lies the economy of an electrical source of heat for many purposes, for it is possible to have the source of heat at a much higher temperature than that required in the substance, so that the transference of heat is very rapid. In the case of the experiments with the muffles, the desired temperature was below that of the fusion of the materials of which the muffle was composed, but it was so close to it that there would have been no advantage in using an electrical source of heat.

In many purposes for which the electrical furnace is used, the ordinary refractory materials, such as silica, magnesite, dolomite, etc., may be used; but where the temperature is much above that used in ordinary furnaces it becomes necessary to look for some other substances. The most promising substances for this purpose are found in certain products of the electric furnace, and special reference will be made here to certain compounds of carbon and silicon which seem to be of considerable value as refractory materials.

The earliest literature bearing on refractory compounds containing silicon and carbon or silicon carbon and oxygen is found in certain papers read by Colson and Schutzenberger in 1881 before the Paris Académie des Sciences. In one of these they describe an experiment in which they heated silicon strongly in a porcelain tube, through which a current of carbon dioxide gas was passed, with the result that the silicon was changed into a green-colored mass which was subsequently purified from silicon and silica by heating in potassium hydrate solution and hydrofluoric acid, respectively. The residue was a green-colored powder which was unattached by acids or alkalies, and was found to correspond to the formula $SiCO$.[1]

In another experiment Colson made a mixture of silicon and lamp black which he raised to a white heat and thus obtained a compound having the composition Si_2C_2O.[2]

By heating silicon in a current of carbon bisulphide Colson obtained the compound Si_4C_4S. When this substance was heated in a current of oxygen SO_2 was evolved without any change in weight of the sample, thus indicating the formation of a compound $Si_4C_4O_2$ (Si_2C_2O) which composition was confirmed by analysis.[3]

In 1892 Schutzenberger presented a paper in which he spoke of the various compounds as having "nearly the same appearance and not clearly distinguishable, except by analysis. They are powders of a more or less pale green color, infusible, stable, unattacked by hydrofluoric acid and caustic alkali solutions, even when concentrated; attacked at a dull red heat by fused potassium hydrate with liberation of hydrogen and formation of potassium silicate and carbonate * * * * *. In all of them the carbon, combined with silicon, resists combustion at a red heat in free oxygen, or by means of cupric oxide, in a remarkable manner. The carbon of these carbo-silicic compounds is not completely burnt execept by heating with lead chromate."[4]

Schutzenberger then goes on to describe how he obtained a new compound, SiC, by heating powdered silicon mixed with silica in a carbon crucible.

In 1893 Acheson, in a paper read before the Franklin Institute, describing the carborundum furnace, said:

"W represents a white or gray-greenish looking shell, surrounding the zone of carborundum crystals. The mass consists of small pieces of the size of the original sand grains These pieces are soft and may be reduced very easily to a fine powder. The qualitative analysis showed that the powder had the same constituents as the carborundum crystals, and the powder was, therefore, cleaned in the same manner as in the case of those crystals. The white-green shell was crushed and alternately heated with hydrochloric acid, caustic soda, water, hot oxygen and hydrofluoric acid. The resulting powder had the following composition:

C	27.93
Si	65.42
Fe_2O_3 and Al_2O	5.09
CaO	0.33
MgO	0.21

"We may say, then, that the powder consists essentially of carbide of silicon. But this carbide of silicon is different from the other one, in that it forms no crystals, is amorphous

[1] Comptes Rendus, XCII., p. 1508.
[2] Comptes Rendus, XCIV., p. 1316.
[3] Comptes Rendus, XCIV., p. 1526.
[4] Comptes Rendus, CXIV., p. 1087.

and very soft, and of no value as an abrasive. It has been obtained at a comparatively low temperature—far distant from the core—and is identical with the product recently obtained by P. Schutzenberger."[5]

In 1896 F. Leuermann published the results of his investigations on the use of silicon carbide as a substitute for ferro-silicon, and asserted that the amorphous form of that compound was insoluble in molten steel.[6]

In 1899 a patent was granted to Benjamin Talbot for a "Lining for Metallurgical Furnaces." In the specification Talbot says he has found carbide of silicon to be very refractory under high temperatures, and that it resists the fluxing action of acid and basic slags. To use the carbide as a refractory material it is mixed with some suitable binding agent and moulded into forms, such as bricks, etc. He prefers to use the amorphous form of silicon carbide, since "that has hitherto been deemed a waste product and is consequently inexpensive."[7]

In 1900 Engels obtained a patent for fireproofing materials by coating them with carborundum, which was afterwards caused to unite with the material by fusing (!) the carborundum with an arc. Later he took out two more patents along similar lines.[8]

In 1903 two patents were issued to E. G. Acheson: One on a "Method of producing compounds containng silicon, oxygen and carbon;"[9] the other on a "Refractory material."[10] The refractory material is called "siloxicon," and contains silicon, carbon and oxygen. The siloxicon is produced by heating in an electric furnace a mixture of carbon and silica, the latter being in excess over the amount required for the formation of silicon carbide. An experiment is described in the specification, and the resulting substance gave the following analysis:

Silicon	57.7
Carbon	25.9
Iron	2.1
Aluminium	0.4
Calcium	trace
Magnesium	trace
Oxygen (by difference)	13.9
	100.0

Various compounds appear to be formed according to the methods of manufacture. Acheson says:

"Thus I have made in this way a compound corresponding approximately to the composition Si_2C_2O, which has been described by Colson as resulting from an oxidation of the compound Si_4C_4S, or from heating silicon in carbonic acid gas. (*Comptes Rendus*, 1882; 94, page 1526.) I have also made analogous compounds wherein the silicon and carbon are in atomic proportions, but wherein their ratio to the oxygen varies within considerable limits. For instance, I have produced a compound Si_7C_7O."

Siloxicon is described as having a density of 2.73; a gray-green color when cold, and light yellow when heated to 300° Fahrenheit or over; the property of forming a coherent mass when ground, moistened with water, moulded into a form and fired; a very refractory nature; a neutral action with both acid and basic slags; as being insoluble in molten iron; indifferent to all acids except hydrofluoric acid which attacks it slowly; finally, it resists the action of hot alkaline solutions. Acheson has also shown that siloxicon is oxidized at high temperatures in an oxidizing atmosphere. Assuming the compound to have the composition Si_2C_2O, the oxidizing action probably takes place according to the following equation: $Si_2C_2O + 7O = 2SiO_2 + 2CO_2$.[11]

In *The Foundry* of August, 1904, F. J. Tone describes "Carborundum Firesand," a name applied to the amorphous substance found outside the zone of crystalline material in the carborundum furnace. It is said to be formed at a temperature "between 6000° and 7000° Fahrenheit." Chemically it is "a compound of carbon with incompletely reduced silica;" it always carries a certain proportion of free silica; it has a specific gravity of 2.7; it is grayish green in color, and has a low heat conductivity. It is said to be an excellent material for furnace linings.

This completes the review of the principal literature relating to the amorphous compounds of carbon and silicon, or carbon, silicon and oxygen. The subject has been treated at some length because it is believed that these substances, which for convenience may be called *silico-carbides*, will prove of value in the construction of electric furnaces. The silico-carbides obviously have their limitations, among which may be noted their conversion into carborundum at high temperatures. However, there is a considerable range of temperature between that at which ordinary refractory materials break down, and the temperature of formation of crystalline silicon carbide. For this range of temperature the silico-carbides will be of value. There has been very little published as to the use of the silico-carbides in electric furnaces, and in what follows some of the results of the experimental work of the writer, with the collaboration of Mr. P. McN. Bennie, are given.

As an example of the application of the silico-carbides to electric furnace construction, it will be found that in many cases a comparatively thin layer of the substance will effectually protect fire bricks from fusion. A very simple form of furnace, useful for some purposes, may be made by forming a trough of fire bricks, placing the terminals connected with the source of current at either end and then filling the trough with granular carbon which serves as the heating resistance. If the temperature of the granular resistance is raised to a bright white heat, the bricks will be fused and the working of the furnace will be unsatisfactory. This can be effectually prevented by lining the trough with a layer of a silico-carbide. Assume, for example, that it is desired to embed crucibles in the granular resistance for the purpose of melting a ferro-alloy. The trough is then built about two inches deeper and four inches wider than is needed for the proper cross-section of the heating resistance. A layer of the silico-carbide, two inches thick, is spread on the bottom of the trough; pieces of sheet iron are then set up two inches away from the side walls of the trough, and the spaces between the walls and the sheet iron filled with the silico-carbide. Finally, the space between the sheet iron pieces is filled with the granular carbon, and the crucibles put in place. Where the temperature is not excessively high this method gives very satisfactory results.

To substitute bricks made of a silico-carbide for fire brick, dispensing with the latter altogether, is not advisable, since the silico-carbides are much better heat conductors than ordinary fire bricks. Hence, if they are used alone they cause a serious loss of heat and should not be used, except in those places where a good heat-resisting material is required.

In F. J. Tone's article, already quoted, a low heat conductivity is spoken of as characteristic of "Carborundum Firesand." An experiment illustrative of this characteristic is described as having been performed by a certain manufacturer of tilting furnaces.

"With fire brick linings first employed it was possible to obtain from five to six heats per day. With the first trials of carborundum firesand nine to ten heats were easily run, and he expects to reach a still higher efficiency. The exterior of

[5] Journal of the Franklin Institute, September, 1893.
[6] Zeitschrift für Electrochemie (1896), 111., p. 113.
[7] U. S. Patent 628,288, July 4, 1899.
[8] U. S. Patent 650,040, May 22, 1900; U. S. Patent 734,457, July 21, 1903; U. S. Patent 734,458, July 21, 1903.
[9] U. S. Patent 722,792, March 17, 1903.
[10] U. S. Patent 722,793, March 17, 1903.

[11] Electrochemical Industry, Vol. I, No 11, p. 373.

the furnace is cool enough to rest one's hand on the shell, and the plain inference is that the refractory we are discussing is an exceptionally good insulator of heat."

Unfortunately, the kind of fire brick lining compared with the carborundum firesand is not mentioned. Nor is it explained whether the lining used in the experiment was composed of the carborundum firesand alone, or whether it was backed with fire brick. The insulating properties of the silico-carbides may be greatly improved by keeping them in a porous state; but according to the writer's observations the silico-carbides are not good heat insulators. This was well illustrated in the case of a small gas furnace, where siloxicon was substituted for the fire clay lining, with the result that although a steel melt could easily be obtained in the furnace under ordinary conditions, the heat was conducted away so rapidly by the siloxicon that it was almost impossible to melt copper.

It is well known that those substances which are excellent electrical insulators at ordinary temperatures become to a greater or less extent conductors when raised to a high temperature. The phenomenon is frequently observed in the working resistance furnaces and becomes marked where the heating resistance has a high resistivity. This is illustrated in furnaces of the Cowles type where a current is passed through a mixture of an oxide and carbon which has a high resistance, for if the lining of the furnace becomes very hot there will be distinct current leakage. In a resistance of granular graphitized coke, the leakage effect is far less marked, since the ratio of the electrical resistances of the lining and the heating resistance is always great.

Fortunately, the silico-carbides are fairly good insulators, though they probably are better conductors than ordinary fire brick, heated to the same temperature. We have made an experiment with the object of gaining some information on this point, the conditions being so adjusted as to obtain the maximum leakage effect.

A small box was built with the bottom, and two sides composed of silico-carbide tiles, 12 inches long, 6 inches wide and 2 inches thick. The tiles were made by mixing three parts of the silico-carbide with one part of tar and the mixture tamped into moulds which were then baked at a high temperature in a non-oxidizing atmosphere. The silico-carbide used contained about 5 per cent of free carbon in the form of graphite, and in addition to this there was the carbon deposited from the tar, so that the conditions were very favorable for considerable leakage of current. The ends of the box were formed of graphite blocks which were connected with a source of electric current. When finished, the inside dimensions of the box were: Length, 12 inches; width, 1½ inches; depth, 6 inches. The box was filled with granular graphitized coke, contact between the granular coke and the graphite blocks being made by graphite powder tightly rammed into place. The graphite powder also made good electrical contact between the blocks and the silico-carbide tiles.

The current was then thrown on, and when the tiles were raised to a good red heat, the ammeter reading was taken, also the voltage difference between the graphite blocks. One of the tiles forming the side of the box was then removed and the granular carbon quickly raked out. The moment this was done, and before appreciable cooling of the remaining tiles had taken place, the ammeter and voltmeter readings were again taken. The results obtained were as follows:

	Before removal of granular coke.	After removal of granular coke.
Ammeter	340 amps.	100 amps.
Voltmeter	15 volts	33 volts
Sectional area of granular coke	9 sq. ins.	0 sq. ins.
Sectional area of tiles (total).	36 sq. ins.	24 sq. ins.

The explanation of the increased voltage after the removal of the granular coke is that there was a resistance in series with the box; consequently, when the coke was removed, there was a redistribution of the development of energy in the circuit.

Now let the electrical conductance of the box before removing the granular carbon be C, and after removal of the carbon be c, then,

$$C = \frac{340}{15} = 22.7.$$

$$c = \frac{100}{33} = 3.0$$

Since the sectional area of the tiles was 24 square inches when the granular carbon was removed, the value of the conductance for a sectional area of 36 square inches would be,

$$3.0 \times \frac{36}{24} = 4.5$$

and the conductance of the granular carbon would be,

$$22.7 - 4.5 = 18.2$$

Since the conductance varies directly as the sectional area of the conductor, we have for the ratio of the conductivities the following equation:

$$\frac{\text{Conductivity of granular carbon}}{\text{Conductivity of silico-carbide tile}} = \frac{18.2}{4.5} \times \frac{36}{9} = \frac{72.8}{4.5}$$

From this result it may be deduced that in a furnace having a carbon resistance of the kind used in the experiment, with solid walls of silico-carbide, of which the total sectional area was the same as that of the carbon resistance, and with all other conditions the same as in the experiment, about 6 per cent of the current would be lost by leakage.

In actual practice, however, there would not be any such leakage for all the conditions of this experiment were such that the leakage was a maximum. The experiment, therefore, must be considered as an exaggerated case serving to illustrate the possibilities of leakage.

As to the best method of moulding silico-carbides into forms such as bricks or tiles, it depends to a certain extent on the use to which they are to be put. When the material is put directly into place in the furnace, where it will not have to undergo any serious mechanical strains, a mixture of the powdered silico-carbide, and a solution of glue in water gives satisfactory results. In order to obtain the best results with this method the mixture should be used hot. In those cases where very high temperatures are reached this method of making bricks is to be particularly recommended, for the silica which is usually present in commercial silico-carbides is fused at high temperatures, and thus strengthens the article considerably.

When there is no free silica present, and the article is made up with the glue solution, it becomes very weak and crumbles after use. It is, therefore, advisable to analyze the silico-carbide before using, and if there is no silica present a small quantity may be incorporated with the mixture. The best form of silica for this purpose is infusorial earth. The presence of silica is sometimes objectionable, as will be shown later.

In cases where the bricks will not be exposed to such high temperatures the silico-carbide may be mixed with a dilute solution of sodium silicate. The solution used for this purpose should not, as a rule, have a greater density than 1.03 to

1.05. Tone recommends a solution having a density of 33° Beaumé (1.277), but this is for ordinary furnaces, where relatively low temperatures are used. For high temperature work a solution of this density would introduce too much sodium silicate for satisfactory results.

A very satisfactory bond for silico-carbides is found in gas tar. A good mixture contains 4 parts of the silico-carbide to 1 part of tar. In using tar, however, it must be remembered that a residue of carbon is left in the article, and this tends to diminish the insulating properties of the silico-carbide. It should also be noted that if the article is exposed at high temperatures to an oxidizing atmosphere the carbon residue which acts as the binding agent is burnt out. If this happens the article will disintegrate, unless the temperature and oxidizing conditions are such as to cause oxidation of the silico-carbide and consequent binding together of the particles as discussed below. When, therefore, the article is exposed to oxidizing actions and a comparatively low temperature, it is better to use sodium silicate as the binding agent. But where the conditions are such that neither oxidation or serious current leakage is to be feared, the tar bond is very satisfactory, giving articles of considerable mechanical strength.

When an article of great mechanical strength is required, and the use of tar is objectionable, the best method of making the article is by causing the particles of the silico-carbide to frit together by oxidation. To accomplish this result the silico-carbide is mixed with some temporary binding agent, such as a solution of glue in water and then heated to a high temperature for several hours in a strongly oxidizing atmosphere. By this treatment the grains of the silico-carbide are superficially oxidized. In the case of amorphous silicon carbide this would take place according to the equation:

$$SiC + 4O = SiO_2 + CO_2$$

If the article made in this way is examined under a strong lens, it will be seen that the grains of carbide are superficially oxidized and fused together in that way. By this method articles of great mechanical strength can be made. It should be noted here that the formation of silico-carbide articles by the oxidation method requires prolonged heating, since the rate of oxidation is slow, proceeding gradually from the outside of the article to the center.

The use of silico-carbides is limited to certain temperatures, for, beyond a certain temperature, crystalline silicon-carbide (carborundum) is formed. Judging from the literature on the subject, the silico-carbides vary greatly in their composition, although, as Schutzenberger pointed out, their general properties seem to be similar. If a silico-carbide article, composed substantially of amorphous silicon-carbide, is heated to the temperature of formation of carborundum, the change produced is simply one of physical characteristics: The amorphous substance is converted to the crystalline state.

Another important change takes place if silica happens to be present, for the silicon is produced according to the equation:

$$2SiC + SiO_2 = 3Si + 2CO$$

The silicon thus produced may remain, for some time at least, distributed throughout the article; but if the temperature is high, it will be rapidly vaporized.

If the article is assumed to be substantially composed of a compound having the formula $Si_xC_xO_y$, then at high temperatures decomposition according to the following equation takes place:

$$Si_xC_xO_y = (x-y)SiC + ySi + yCO$$

The reactions that take place when silica or a silico-carbide containing oxygen are present must be kept in mind, since the presence of silicon vapors in the furnace may be objectionable.

While considering the effect of the presence of silica in the refractory material it is well to note that silica has an appreciable vapor tension even at relatively low temperatures. This fact was recently noted by Moissan in connection with some experiments on the action of lime and carbon when heated to the temperature of fused platinum. In his experiments, Moissan placed a graphite boat containing a mixture of lime and sugar-carbon in a silica tube. The tube was placed in a small furnace built of blocks of lime and heated by an oxygen and illuminating-gas flame. Moissan says:

"Repeating and varying this experiment we observed a somewhat interesting fact; this is, that silica has an appreciable vapor tension at a temperature below that at which softening takes place. Accordingly, when heating the mixture of carbon and lime to about 1200° C. small needles of silicate of calcium, insoluble in water or dilute acids, are seen to form slowly on the surface of the lime. This appreciable vapor tension of silica below its temperature of fusion will, unfortunately, limit the number of experiments that may be performed at high temperatures in silica tubes."[12]

This vaporization of silica at relatively low temperatures seems to be confirmed by a common phenomenon in electric furnaces. Where carbon and silica are both present, although not necessarily in contact, specimens of the former are frequently found to be covered with a green-colored deposit which, on examination, is found to be the amorphous form of silicon-carbide. It follows, therefore, that in using the silico-carbides as refractory materials, it is necessary to keep in mind this appreciable vapor tension of silica, when for any reason it is undesirable to have silicon present as an impurity.

When the temperature to which the refractory material is submitted may be up to or above that of the formation of carborundum, it may be advisable to use crystalline silicon-carbide in the first place. It is possible, however, to use a silico-carbide at first, allowing it to be converted into carborundum *in situ*. If this is done the silico-carbide should first be analyzed to determine whether oxygen compounds are present or not. If oxygen compounds are present in appreciable quantities the silico-carbide may be unsuitable for the work. Assume, for example, that the silico-carbide is mainly composed of amorphous silicon-carbide, but that a certain amount of silicon is present: then at the temperature of formation of carborundum the following reaction will take place:

$$SiO_2 + 3SiC = SiC + 3Si + 2CO$$

The result is that the refractory article or lining will be impregnated with metallic silicon, or the furnace will be filled with silicon vapor. When the presence of the silicon is unobjectionable this reaction may be disregarded; otherwise there are two courses open:

(1) The silica may be removed or a material free from silica obtained.

(2) From the analysis of the material the amount of carbon necessary to eliminate the oxygen and to form carborundum may be added to the mixture.

When it is desired to use carborundum directly as a refractory material the binding agents already suggested for silico-carbides may be used. Carborundum may also be made into a strong article by the oxidation method as described when dealing with the silico-carbides.

Another method of making articles of carborundum is by recrystallization. The carborundum in the form of grains or powders is mixed with some adhesive substance, such as a solution of glue in water, the mixture moulded in the desired form and the article then placed in an electric furnace and heated to the temperature of formation of carborundum. This causes a recrystallization of the carborundum and forms a strong article which preserves perfectly the form in which it was moulded.

[12] Comptes Rendus (1904), CXXXVIII., p. 244.

The current leakage effect at high temperatures seems to be somewhat more marked in carborundum articles than in the case of the silico-carbides.

Neither the silico-carbides nor carborundum can be used as refractory materials where they come in contact with fused alkalies, since these produce rapid decomposition. They are also attacked by chlorine at high temperatures. It is said that siloxicon and carborundum firesand are not attacked by molten metals or slags, whether acid or basic. While this may be true at relatively low temperatures, it most certainly is not true so far as high temperatures, such as those attained in the electric furnace, are concerned. If carborundum or the silico-carbides are in contact with fused fire brick, for example, at a high temperature, there is a marked reaction, with the formation of a silicon-aluminium alloy.

The temperature limit to the use of carborundum is reached when that substance decomposes according to the equation:

$$SiC = Si + C$$

the silicon escaping as vapor, while the carbon remains as graphite. When the temperature is so high that this decomposition occurs, there appears to be no refractory material that can be used, except carbon. The best form of carbon for this purpose is charcoal, since its electrical resistivity is high. Where carbon cannot be employed then the furnace must be so constructed that the use of a refractory material at the place of high temperature can be dispensed with. That subject, however, belongs rather to furnace design than to a discussion of refractory materials.

It seems that where temperatures higher than those at which ordinary refractory materials can be employed are obtained, we are confined to the use of the silico-carbides, carborundum and carbon. All these have their disadvantages; but so far there does not appear to be any remedy. However, it is to be hoped that with further study of electric furnace products other refractory materials will be discovered that may be used where those discussed above are unsatisfactory.

No attempt has been made here to discuss the chemistry of the silico-carbides. The literature on the subject seems to show that there are several different compounds of variable composition, and it may be that their properties vary with the chemical composition. It was pointed out that it is sometimes necessary to analyze the silico-carbide, and in such cases the following methods have been found to give good results, fulfilling all technical requirements. The methods also apply to the analysis of carborundum.

Analysis of Silico-Carbides and Carborundum.

Preparation of Sample.—The sample must be reduced to a very fine powder. This is highly important, for, unless the powder is very fine, decomposition by the reagents employed will not be complete.

Free Carbon.—A weighed portion of the sample is heated in an open porcelain crucible, the contents being frequently stirred with a platinum wire. It will be found advantageous to support a long piece of combustion tube to bring vertically over the crucible, thus creating a draught of air over the contents of the crucible, causing the more rapid combustion of the carbon. When the carbon is completely burnt the crucible and its contents are weighed, the loss in weight giving the free carbon. The result obtained may be too low, even if the carbon is completely burnt, because of oxidation of the silico-carbide or carborundum, as the case may be. The error introduced in this way, however, is small, unless the crucible has been raised to a very high temperature.

Free Silicon.—A weighed portion is digested with a concentrated solution of sodium hydrate, the solution diluted, filtered off and the silica separated from the filtrate in the usual way. If the sodium hydrate solution contains sodium silicate an appropriate correction must be made. A small error is introduced here, in all probability, by the presence of silica in the sample. A more serious source of error is that due to the presence of silicides, which are decomposed by the caustic soda solution. In analyzing commercial silico-carbides, the caustic soda solution is always found to contain an appreciable amount of aluminium, probably derived from the decomposition and solution of silicon-aluminium alloys. Strictly speaking, then, this method determines free silicon and silicon derived from certain alloys.

Silica.—The unattacked residue from the silicon determination is weighed and digested with hydrofluoric and sulphuric acids. When no further action is observed the excess of hydrofluoric acid is driven off by heating, the residue diluted with water, and the solution filtered off. The iron, aluminium, etc., are determined in the filtrate and the residue on the filter dried and weighed. The difference of the weights of the residue plus the iron aluminium, etc., and the original substance gives the silica present. According to Acheson siloxicon is slowly attacked by hydrofluoric acid, which would introduce a variable error into the determination. However, for technical work where the object is to determine the amount of carbon to be added to the silco-carbide, in order to avoid the formation of silicon, the method given has been found satisfactory.

Combined Silicon.—The residue from the silica determination is fused with a mixture of equal parts of sodium and potassium carbonates to which a little potassium nitrate is added. The fused mass is digested with water and the silica separated in the usual way, weighted and calculated to silicon.

Combined Carbon.—A weighed portion, about 0.3 gram, of the sample from which free carbon has been burnt off is mixed with about 8 grams of a mixture of calcined magnesia (1 part) and sodium peroxide (2 parts) in a nickel crucible. The weight of the magnesia and sodium peroxide mixture used must be known so as to correct for CO_2 present, this being determined in a blank experiment. The crucible is then heated with a hydrogen flame until a vigorous reaction, accompanied by a considerable generation of heat occurs, which usually happens in less than a minute. The crucible is then transferred to a desiccator charged with soda-lime and allowed to cool, after which the CO_2 is determined by any suitable means. After applying the correction for CO_2 present in the magnesia and sodium peroxide mixture, the carbon in the sample may be calculated.

For most work it is not necessary to make all these determinations. It is simply necessary to determine free carbon, combined carbon, total silicon, metals. Then the oxygen present can be determined by difference. If, however, free silicon happens to be present it ought to be determined. The following example from actual practice illustrates the use of the analysis.

The silico-carbide gave the following analysis:

Carbon (free)	4.63
Carbon (combined)	21.48
Silicon (total)	58.03
Aluminium	4.21
Iron	1.52
Calcium	1.22
Oxygen (by difference)	8.91
	100.00

The amount of silicon required by 21.48 grams of carbon to form SiC is 50.84. Subtracting this from 58.03 we have 7.19 grams of silicon which requires 8.10 grams of oxygen to form SiO_2. It is then assumed that 15.29 per cent of silica is present and to convert 15.29 grams of silica to silicon-carbide require 9.11 grams of carbon. But in 100 grams of the silico-carbide there are already 4.63 grams of free carbon, therefore the amount of carbon to be added is only 4.48 grams.

It is probably incorrect to assume that all the silicon not combined with carbon is present as silica; but the method used for calculating the proper amount of carbon to add to the silico-carbide in order to avoid the formation of silicon is found to give good results in practice.

If, for any purpose, it is desired to obtain very pure amorphous silicon-carbide, the commercial material, after burning off free carbon, must be repeatedly digested with hydrochloric acid. It is then repeatedly digested with hydrofluoric and nitric acids, followed by sulphuric acid. Finally, it is thoroughly washed with water. A sample prepared in this way gave the following analysis:

Silicon	69.41
Carbon	29.18
Iron and aluminium	0.59
	99.18

This corresponds closely to the theoretical composition of silicon-carbide. Taking the proportions of the silicon and carbon, we have:

	Found.	Theory.
Silicon	70.40	70.30
Carbon	29.60	29.70
	100.00	100.00

The substance might then be considered as nearly pure amorphous silicon-carbide.

COLLOIDAL PRECIPITATION UPON ALUMINIUM ANODES.

By William Roy Mott.

Engineers and inventors have repeatedly emphasized the importance of selecting the *proper electrolyte* for use with the aluminium electrolytic rectifier and condenser, and yet little has been done to answer the pertinent question: "What principles will guide us to new and better electrolytes?" Other important questions present themselves. Why does an insulating film form? What is its exact composition? Why are nitrate solutions unsuitable? Why do films formed in citric acid resist even 500 volts? Why is film formed at 20 volts with sulphates several times thicker than a film formed at the same voltage with phosphates? An attempt will be made to answer these questions.

The mode of formation of the insulating film, its composition and chemical nature will here be considered in the light of the general phenomena of colloidal precipitation. Solutions of chromates, phosphates, tartrates, citrates, etc., strongly precipitate colloidal aluminium hydroxide. These same electrolytes produce insulating films upon aluminium anodes. These films also show absorptive phenomena similar to that observed in colloidal precipitation. These facts suggest that film formation at an aluminium anode and colloidal precipitation are closely allied phenomena. The first consideration is the composition of the film.

Composition of the Film.

For a long time a great diversity of opinion has prevailed as regards the composition of the insulating film that forms upon aluminium anodes. Since the film formation occurs only with electrolytes producing oxygen at the anode, therefore this film has frequently been considered some oxide of aluminium. Since, however, different electrolytes produce films of vastly different character, a difference of composition in the film is expected with each electrolyte. For example, the film formed with sulphates, we may suppose to be basic aluminium sulphate, and that with phosphates, basic aluminium phosphate. To the generalization that the insulating film is always a basic salt, exception may be taken. For instance, distilled water has repeatedly been shown to cause high polarization of aluminium electrodes. For these and other reasons, we have to consider the following four possible compositions which have been ascribed to the film: (1) sub-oxide of aluminium, (2) oxide (Al_2O_3) of aluminium, (3) hydrate of aluminium, and (4) basic salt of aluminium. The evidence for and against each of these theories will be briefly presented.

That the film is a sub-oxide of aluminium was proposed by Beetz (1866). First, Beetz proved that the film is not silicon. Buff (1857) had suggested this idea—plausible enough, in view of the large amount of silicon contained as an impurity in the aluminium. Next, Beetz attempted to show that the film is a sub-oxide of aluminium by the following method. The total coulombs passing through the electrolytic cell were measured by a silver voltameter. This current does work in three directions which were separately studied.

First, the changes in weight of the aluminium anode were determined.

Second, the aluminium dissolved from the electrode by the electrolyte (dil. H_2SO_4) was determined by analysis.

Third, the oxygen gas liberated at the anode was collected and measured.

On adding up the electrochemical equivalent of the free and combined oxygen there was found a deficiency of 5 to 10 per cent. This deficiency Beetz explained as due to the formation of a film of sub-oxide of aluminium. However, the percentage of oxygen actually required for the film was small and well within the limits of experimental error! Wiedemann (1879) called attention to certain sources of error in Beetz's work. We may conclude, therefore, that, as yet, there is no real evidence in favor of sub-oxides or sub-salts of aluminium.

Oxide films were supposed by Faraday (1837) to explain the passive state of iron. Wheatstone (1855) and Heeren (1856) applied the same explanation to the behavior of aluminium electrodes in nitric acid and other electrolytes. That the film is oxide of aluminium has been the opinion of Planté (1859), Henrici (1864), Ducretet (1875), Ramann (1880), Neyreneuf (1888), Tommasina (1899), Fessenden (1899) and Cook (1904). Tommasina showed that a slightly oxidized aluminium electrode was the more luminescent in distilled water. Cook found that the coulombs required for forming the film apparently corresponded best with the idea of an oxide layer, but several losses were not investigated by him, and further in his most careful work he found the aluminium anode to weigh *more* than his theory required. Hence, we should look to the other two theories, the hydrate and basic salt.

Haagn (1897) calls the film a "hydroxide of aluminium." Lecher (1898) suggested an oxide film that changes over into a hydrate. He, however, says: "The explanation of the chemical part of the process is still surrounded with difficulties." The avidity for water is strong, so that only high temperature will dehydrate aluminium hydroxide. All analyses of films formed in aqueous solutions showed the presence of considerable water.[1]

But other substances are found in sufficient quantities, so that the film cannot accurately be called aluminium hydroxide.[2]

The oxide and hydrate theory have never been held as altogether satisfactory. Slouginoff[3] (1878) was contented to

[1] The formation of an insulating film with fused electrolytes and the separation of metallic sodium in their neighborhood shows that water or hydroxyl is not always a necessary constituent of the film. An analysis of these films would be of considerable interest. See Carl Hambuechen. "Trans. Am. Electrochem. Soc., 4, p. 106 (1903).

[2] Three hydrates of aluminium oxide, $Al_2O_3.H_2O$, $Al_2O_3.2H_2O$ and $Al_2O_3.3H_2O$. are known. Preference falls on $Al_2O_3.3H_2O$; and this is plausible in view of Cossa's experiments (Il nuovo Cimento (2), 3, p. 75, 228). The normal hydroxide is formed in transparent, iridescent laminæ by bringing dilute aluminium amalgam in contact with a large amount of water. The hydrate, $Al_2O_3.2H_2O$, was obtained by Crum by drying at 100° his colloidal compound. Becquerel favored $Al_2O_3.H_2O$.

[3] The work of this Russian scientist has been sadly neglected. Besides observing the iridescent, very hard films on aluminium anodes, he measured the high discharge potentials of aluminium and bismuth electrodes. Bismuth gave better results than aluminium. This is of interest in connection with Schonbein's observations upon the passivity of bismuth (Fogg Ann., Vol. 43, p. 1, 1838), and it is also of interest as regards the high discharge potentials observed by Isenberg (1903) with lead electrodes. The capacity of these electrolytic condensers has not yet been measured.

say that the film consists of "aluminium oxide, hydrate or other aluminium compound." Jahn (1895) expressed his opinion that the insoluble film, formed on aluminium anodes in sulphate solutions, is "apparently of basic aluminium sulphate." Views of equivalent effect have been expressed by Raveau (1902) and Snowdon (1904). We will now turn to the final test of the whole matter: The actual analysis of the anode film. This is the only conclusive test of its composition.

Becquerel (1861) published a valuable article entitled "Mémoire sur la production électrique de la silice et de l'alumine hydrates" (Memoir upon the electrical production of hydrates of silica and aluminia). Thirty years prior to this time Becquerel had done work on the electrical production of mineral substances at low tension; but for this latter work, he used current at high tension. He obtained a deposit on aluminium anodes in potassium silicate solutions. He says, "It is remarkable to see a substance formed so rapidly acquire such extreme hardness." Then he reports the analysis made by M. Terreil and M. Fremy as follows:

Alumina	69.70
Silica	12.30
Water	18.00
	100.00

Becquerel considered (aside from the silica) the anode product closely related to diaspore ($Al_2O_3 + H_2O$).

Wilson (1898) separated the insulating film from the aluminium electrode by subjecting the same, immersed in mercury, to the electric current. This film was then analyzed by H. Jackson, who found it to be basic aluminium sulphate.

K. Norden (1899) detached the film in another way—by alternately using the aluminium as anode and then allowing it to stand in contact with the solution. Sufficient quantity of the film was obtained in this way to enable exact analysis to be made. The average of three experiments gave the following results:

	%
Al_2O_3	69.8
SO_3	13.2
H_2O	14.8
SiO_2	2.2
	100.0

The author, by using aluminium foil as anode in sulphate solution has obtained sufficient of the film for analysis which showed a little more SO_3 than Norden found.

These four independent analyses show conclusively that the insulating film consists of aluminium hydrates combined with basic salts of aluminium, or stating it another way; the film consists of aluminium oxide, water and acid radical.

For some time, the opinion has been advanced by Wilson and Norden that aluminium hydroxide is first formed and then this reacts with the electrolyte to take up the acid radical. It is first necessary to know if we can substitute an aluminium hydroxide film for the aluminium anode. This has been successfully done by Taylor and Inglis[4] who deposited aluminium hydroxide in the walls of a porous cup. With this membrane between platinum electrodes, they reproduced the peculiarities of the aluminium anode. The conclusion is that aluminium hydroxide is first produced on the aluminium anode, and this reacts with the electrolyte. This phenomena of taking up acid radical is called adsorption.

[4] Taylor and Inglis regard the films as semi-permeable membranes that allow the so-called ions, H, Cl, Br, NO_3, etc., to freely diffuse through the films in the same selective way that sieving is done in a mill. The ions are supposed to be independent of each other and to squeeze through minute holes in the copper ferrocyanide or other membrane. The efficiency of the semi-permeable membranes, used in determining osmotic pressure, has been called in question by Quincke. (See Wied. Ann. 3, p. 631, 1902.) The author considers that mechanical sifting of ions does not explain the behavior of aluminium hydroxide films. The film forms a chemical compound with sulphur trioxide, which effectually stops further diffusion and at the same time changes the nature of the film. As in most cases, the compound is different in properties from its constituents.

ADSORPTION.

Aluminium hydroxide has strong affinity for adsorbing acid radical. This power is shown in colloidal precipitation, in ordinary precipitation and even in washing the precipitated hydroxide with electrolytes. The effect of adsorption upon the character of the film is important, as will be shown later.

The phenomenon of adsorption is a well-known characteristic of colloidal precipitation. The precipitated colloid (or coagulum) is always contaminated with portions of the precipitating electrolyte. In some cases the acid portion of the electrolyte is carried down; in others, the basic portion. The latter case is illustrated by the precipitation of colloidal solutions of Sb_2S_3 and As_2S_3, which split off the metal or base of the electrolyte, and so leave free acid in the solution.[5]

The acid radical affects only slightly the precipitation of these colloids. Salts of trivalent metals (Al) precipitate these sulphides much better than salts of divalent metals (Ca, Zn, etc.), which in turn surpass in precipitating power salts of monovalent metals. This interesting effect of valence will be later applied to the aluminium anode phenomena; but with the difference that the *valence of the acid radical of the electrolyte is the important factor and not that of the metal or base.*

In ordinary precipitation of aluminium hydroxide by alkali hydroxide, trouble is experienced in precipitating aluminium hydroxide from solutions containing sulphates, silicates, etc. The hydroxide adsorbs the acid radical and so destroys the accuracy of the results. (Fresenius).

Patten[6] has determined by exact analysis this adsorptive power for a large number of metallic hydroxides in precipitation with potassium hydroxide. Curves are plotted by him showing the effect of the concentration of the alkaline solution. In the precipitation of alum[7] with four molecules of potassium hydroxide, the precipitate contains 24 per cent SO_3 and 76 per cent Al_2O_3. The water content is not considered.

Ordinary precipitated aluminium hydroxide is used to purify alcohol, etc., because of its adsorptive powers. Warington (1868) washed aluminium hydroxide with various solutions and found marked adsorption of the acid radical leaving the solution alkaline. Analysis showed the amount adsorbed to be greatest with carbonate, less with sulphates and least with nitrates and chlorides. In this order of electrolytes we find an analogy to the electrolytes that insulate the aluminium anode. Nitrates and halogen salts do not cause insulation. Sulphates are effective, but carbonates are better. Carbonates and sulphates contain divalent acid radicals, while nitrates are monovalent. This brings us again to the valence idea. But first, we would inquire as to what changes take place in the properties of the film due to this adsorption.

Aluminium hydroxide is precipitated by ammonia from a chloride solution in a loose, flocculent form which is easily soluble in hydrochloric acid and in alkalies. When this precipitate is left standing for a long time in contact with sulphate solutions, it becomes, as is well known, more and more insoluble in acids and even alkalies. This slow chemical process takes place with great rapidity at an aluminium anode. The loose, incoherent aluminium hydroxide is compacted together into a dense[8], very hard, insoluble film of great specific resistance and high dielectric strength.[9] Slouguinoff found that films formed slowly on aluminium anodes

[5] See Whitney and Ober. Jour. Am. Chem. Coc., 23, p. 857 (1901).
[6] See Am. Chem. J., 18, p. 608; Am. Chem. J., 25, p. 186 (1903).
[7] See "A Thermochemical Analysis of the Reaction Between Alum and Potassium Hydroxide," by Young. Am. Chem. J., 8, 23.
[8] The exact specific gravity of the film is quite important. See Dimensions of the Films, etc., ELECTROCHEMICAL INDUSTRY, July 1904.
[9] See Electrical Properties of the Films, etc., ELECTROCHEMICAL INDUSTRY, September, 1904.

with sulphate solutions are so extremely hard[10] that they resist abrasion by emery paper. He also remarks upon the insolubility of the film in acids and even alkalies. But Beetz has shown that the film is sometimes soluble in alkali; he says: "The film, usually appearing with iridescent colors, dissolves easily in alkali." The author has shown[11] that the film does not prevent the *uniform corrosion* of aluminium by alkaline solutions—the reason being that the oxide and hydroxide of aluminium are soluble in alkali. *However,* this solvent action of alkali on the film is not altogether complete—*a part of the film is not dissolved.* Detached films show this very clearly.

Films have been detached by using formed aluminium plates as anode in copper sulphate solution (containing a trace of chloride). These detached films are insoluble in hydrochloric acid and in alkali. Films formed by using aluminium foil as anode were soluble to a certain extent in sodium hydroxide, but laminæ of the insoluble portion remained unaffected for a long time in even concentrated potassium hydroxide.

The *solidifying* effect of different electrolytes will now be considered in detail.

Valence and Colloidal Precipitation.

The effect of the valence of the *precipitating part* of the electrolyte has long been studied experimentally, and this has resulted in the discovery that the greater the valence the more powerful the precipitation. The law of this influence is not expressed by the usual $1 : 2 : 3 : 4$ ratio, but by a logarithmic function[12] of the valence thus $1 : x : x^2 : x^3$.

If $x = 32$ then the series becomes $1 : 32 : 1024 : 32800$. This corresponds to the power of monovalent, divalent, trivalent and tetravalent radicals.

Crum's (1854) very valuable work on colloidal aluminium hydroxide shows the importance of valence. He found that citric acid (trivalent) coagulates much more powerfully than tartaric acid (divalent) or sulphates. Chlorides and nitrates (monovalent) have one three-hundredths of the power of sulphates.

"Of the other acids which have been tried, the chromic molybdic, racemic, suberic, salicylic, benzoic, gallic, lactic, cinnamic, butyric, valerianic, carbozotic, camphoric, uric, meconic, comenic and hemipinic acids all coagulate the solution; but their exact power has not been ascertained.

The acetic, formic, boracic, arsenius and cyanuric acids do not coagulate at least when moderately concentrated." The alkalies have less power than sulphates.

The above acids and their salts that coagulate colloidal aluminium hydroxide are proportionately efficient as electrolytes for forming an insulating film on aluminium anodes. To show how true this is, we shall briefly review the work done on the various electrolytes.

Electrolytes.

The concentration of the electrolyte is usually of minor importance. *Faraday's law demands that the amount of acid radical transferred to the anode for equal coulombs should be exactly the same, both for very dilute and for concentrated electrolytes.* For this reason, the aluminium anode generally behaves the same in concentrated as in dilute electrolytes. For similar reasons the basic portion of the salt is of minor importance.

Sulphate solutions were discovered by Buff and Planté to cause high polarization of aluminium anodes. Eichberg and Kallir (1898) found that concentrated[13] sulphuric acid is ineffective. Graetz (1896) enumerated soda-alum, potash-alum, dil. sulphuric acid, and alkali sulphates as suitable electrolytes. He observed a discharge potential of 22-25 volts. Guthe (1902) experimented with zinc sulphate and copper sulphate which behave much as other sulphates.

Chromate solutions were first used by Planté (1859). He lays great stress on the effectiveness of silver anodes for stopping the current with this electrolyte. Cail (1878) showed that solutions of chromates are much more effective than sulphate solutions. Battelli (1900) found that aluminium anodes polarize four times as *fast* with chromate solutions as with sulphates. Discharge voltages near 65 volts were measured. By using chromate solution containing a small amount of alkali, Pollak (1898) obtained critical voltages above 100 volts.

Carbonate solutions have been used successfully by several workers. Cail (1878) found them more effective than chromates or sulphates. Carl Liebenow (1898) used carbonate and bicarbonate of ammonia and later Siemens and Halske (1901) claimed that bicarbonates of calcium and magnesium are valuable electrolytes. Mitkiewicz (1901) used sodium carbonate solutions in his aluminium rectifier and condenser. The critical voltage with carbonates lies above 100 volts.

Alkaline solutions have been used, for example, ammonia, alkali aluminates, etc.

Silicates were used by Becquerel (1861) at high tensions with aluminium anodes. Polzenius (1899) observed a critical voltage of 120 volts with aluminium anodes in silicic acid. Borates are a class of electrolytes that Burgess[14] places above tartrates. Phosphate solutions have critical voltages in the neighborhood of 200 volts. Pollak, Polzenius, Nodon and numerous other experimenters have detailed work on the behavior of phosphate solutions.

Other inorganic electrolytes might be enumerated at length; but among *organic electrolytes,* there is a large number which are even more effective.

Pollak (1898) polarized an aluminium anode to the extent of 200 volts in a 5 per cent soap solution. Sodium potassium tartrate ($CHOH - CO_2Na - CO_2K$) has been found effective by Andrews, Franchetti, Rypinski, Berti and others. Burgess and Hambuechen[15] give its critical voltage as near 200 volts at room temperature. Polzenius (1899) has shown, for organic compounds, that a peculiar ratio exists between the critical voltage and the size of the molecule and the number of carboxyl and hydroxyl groups; glycerine ($C_3H_5(OH)_3$) and sugar ($C_{12}H_{22}O_{11}$) giving critical voltages of 40-50 volts, benzoic acid ($C_6H_5-CO_2H$) nil, and critic acid ($C_3H_4(OH)(CO_2H)_3$), 500 volts. Pollak claims that the organic acids and salts should contain in a molecule, *two or more* carboxyl groups ($-CO_2H$), or one or more carboxyl-groups, together with one or more hydroxyl, ketone or aldehyde groups. He cites as examples the acids, malic ($C_2H_3(CO_2H)_2$), tartaric, glyoxalic ($CHO-CO_2H$), phtalic ($C_6H_4(CO_2H)_2$), salicylic ($C_6H_4(OH)(CO_2H)$), and gallic. Siemens and Halske use salts of mandelic acid ($C_8H_8O_3$) with success. The group of acids given by Crum as precipitating colloidal aluminium hydroxide nearly all belong to some one of the above classes which are effective electrolytes for producing high polarization of aluminium anodes.

The general influence of the valence of the acid radical on critical voltage is graphically shown in curve II. of Fig. 1. The abscissæ give the valence of the acid radical; and the

[10] This property of the film reminds one of the precious stones, such as corundum, ruby and sapphire. A suggestion is made that they may be more closely related to our film than might be supposed.

[11] The Corrosion of Aluminium and its Prevention, Electrochemical Industry, April, 1904.

[12] Whetham (Phil Mag., 5, 48, p. 474, 1899) has neatly deduced the same result in a theoretical way. In the author's opinion, more stress should be laid on the chemical phenomena. Whetham postulates that a certain minimum charge be brought within reach of the colloidal group at a certain minimum frequency, in order that coagulation take place. For this conception the author would substitute that a certain minimum number of connecting bonds (or valences) should be brought within reach of the colloidal group at a certain minimum frequency. Then we shall get an equal number of connecting bonds (or valences) by 2n triads, 3n diads or 6n monads, where n is any whole number. The rest of the mathematical deductions follow from the theory of probabilities without change from Whetham's work. The conception of connecting bonds explains the netlike structure assigned to coagulums. It is easy to see that more strength of structure would result from the linking of colloidal groups with two triad atoms than three diad atoms.

[13] This result has been explained by Norden as due to its exceptionally strong solvent action upon aluminium hydroxide and oxide.

[14] Electrical Review, 44, p. 319, Feb. 27, 1904.

[15] Trans. Am. Electrochem. Soc., 1, p. 147 (1902).

ordinates represent the critical voltages on a *logarithmic* scale.

Monovalent acid radicals are quite ineffective either for causing insulation or for precipitating colloids. At the same time there is enough film formed to cause reduced single potentials[16] of an aluminium anode. Chlorates, thiocyonates, nitrates, acetates, formates, chlorides, fluorides, etc., belong to this class of inefficient electrolytes.

Sulphates, chromates, silicates, carbonates and numerous

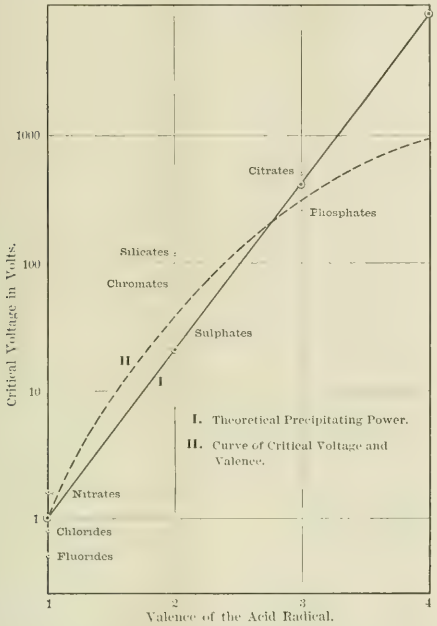


FIG. 1.—PRECIPITATING POWER OF SALTS WITH ACID RADICALS OF INCREASING VALENCE.

organic acids and salts represent divalent acid radicals which are effective electrolytes for producing insulation.

Acid radicals of higher valence are found among citrates, phosphates, antimonates, arsenates, borates, some silicates, some molybdates, some tungstates, etc., etc. Many of these have not been carefully studied as yet. It should also be remembered that in the case of a mixture of electrolytes the insulating power is that obtained with the least effective component of the mixture.

In curve I, is plotted the theoretical precipitating power of salts with acid radicals of increasing valence. The scale of ordinates is logarithmic, and in the units here used $x = 20$ in the series $1 : x : x^2 : x^3$. This series has already been discussed as representing the law of increase in precipitating power of electrolytes of high valence.

The firmness with which the film is formed depends on the precipitating power of the electrolyte. With the increase in solidity comes a corresponding increase in the specific resistance of the film. For this reason, the specific resistance of films formed with phosphate solutions is over ten times greater than that of the films formed with sulphates.

SUMMARY.

Metallic aluminium (when free from the protecting film as in aluminium amalgam) reacts rapidly with water to form aluminium hydroxide. At an aluminium anode, chemical reaction takes place according to Faraday's law between the electrolyte and the aluminium. The loose, incoherent aluminium hydroxide adsorbs acid radical by its great chemical affinity to form a very hard, dense, insoluble solid which possesses great insulating power. The necessary thickness of the insulating film varies with different electrolytes. Citric acid, trivalent, has extreme precipitating power and so films formed at 20 volts are much thinner than those formed in sulphates. This is typical. Electrolytes containing acid radicals of high valence give high critical voltages and films of great specific resistance and high dielectric strength, and so thinner films are obtained—*thus less coulombs are required for the formaton of the film.*

This work is of practical importance. First, numerous new electrolytes are readily found, and second, their more important effects can be predicted. The suggestion is also made that some use may be found in qualitative analysis for phenomena described here.

[16] See Burgess and Hambuechen, ELECTROCHEMICAL INDUSTRY, January, 1903.

OUR CHEMICAL INDUSTRIES AND HOW TO PROMOTE THEM

In a lecture held at the beginning of this year before the Drysalters Club, of New England, and recently published in pamphlet form, Dr. HUGO SCHWEITZER, the well-known Honorary Secretary of the New York Section of the Society of Chemical Industry, points out the enormous progress which the United States has made in recent years in the development of chemical industries. We lead to-day in the metallurgy of iron, copper, silver, aluminium and lead. Our supremacy is established in the petroleum industry, the refining of sugar, the manufacture of starch, glucose and paper. We produce more glass than any other country; we also excel in the manufacture of rubber goods, an industry born in the United States, and in the leather industry. We have developed the manufacture of water gas and originated illumination with acetylene gas. We are the largest producers of glue, lard, tallow and oleomargarine. Our manufacturers of sulphuric acid work to better advantage than their European competitors, and we supply almost as much acid as England, which produces the largest quantity. Our textile industries have grown to such an extent that we manufacture more silken wares than France and more cotton goods than England. Our woolen mills are the largest in the world. We are therefore justified in the general statement that the United States is the leading nation in chemical manufacture, as well as in other industries.

There are, however, some shortcomings in the chemical industries of this country. In 1900 we imported from Europe coal-tar colors and dyes, including alizarines, amounting to $5,563,439, and fine chemicals, drugs, essential oils, amounting to $6,530,037. Against these figures stand the following for domestic production: Artificial dye-stuffs, $2,280,899; fine chemicals, drugs, essential oils $4,206,744. It is only in some particular branches of chemical industry that stimulation is needed.

Dr. Schweitzer points out that it is not one thing or another that particularly stimulates the chemical industry, but a series of factors which are concerned in building it up, and which have resulted in making one European country, Germany, superior to the United States in the production of such chemicals as coal-tar derivatives, medicinal preparations, etc.

The various factors on which the developments of chemical industries depend are discussed one after the other by the author. They are: First, the occurrence in the country of the crude materials to be used as starting points in the chemical processes; secondly, the temperament of the nation, the natural bent of mind of the inhabitants; thirdly, the scientific and technical education of chemists; fourthly, proper co-operation of the government in enacting laws for the stimulation of the industry.

With respect to the second point, Dr. Schweitzer points

out that Germans are inclined to slow, patient plodding, digging into difficult philosophical problems, while Americans desire quick results. For this reason, the United States is backward in the manufacture of coal-tar derivatives and fine chemicals, where the materials entering into the processes must pass through a long series of complicated, tedious reactions before the finished products are obtained. The importations of coal-tar colors in 1900 were $5,563,439. This sum is distributed among about one thousand straight colors; that is, colors representing different chemical individuals. This means a manufacture of many compounds on a small scale. American color manufacturers occupy themselves with the production of a few dye-stuffs for which there is a large demand. The same aversion against working on a small scale is the reason that we still import fine silks from France and Germany and fine woolen goods from England and Germany. Our manufacturers could supply them as well as their European competitors, but they do not care to do so.

With respect to technical and scientific education, Dr. Schweitzer thinks that in this country it is most important to educate the capitalist and the employer of chemists, so far as they are not educated chemically themselves. The employer must be taught that he cannot expect immediate results from the working of the chemist. He must learn patience and let the chemist labor undisturbed. Give a chemist time and means to carry out his ideas and he will solve every practical problem put before him. The synthesis of indigo was a problem which it took about twenty years to solve.

The greatest part of Dr. Schweitzer's lecture deals with the problem of proper co-operation of the government in enacting laws for the stimulation of the industry. In this respect patent legislation is of great importance. The issuing of patents stimulates investigation and improvements, for, if they were not granted, processes and machinery would be worked in secret and industrial development would be delayed and hampered. Dr. Schweitzer thinks that the American patent laws are the best in the world. He answers to criticisms, sometimes directed against the principle of granting claims for products, while Germany grants claims for processes only.

"These critics do not consider that the protection of the process as granted by the German Government is much more valuable than the American process patent, for in the course of a litigation in Germany, the burden of the proof is not on the complainant, but, on the contrary, the party accused of infringement must show by legal evidence that he has committed no wrong. The accused party must admit expert witnesses to their works and prove that the patented process is not employed. According to our laws the burden of the proof is on the complainant, and he has to prove that his rights are injured by the defendant; and the latter can refuse admittance to his factory and state in his testimony that he considers his working process a business secret which he will not reveal. Under the circumstances you will readily see that a process claim in chemical patents affords hardly any protection in the United States, as everybody could infringe a process patent almost with impunity. I suspect that most of the critics of our patent system are advocating changes of our law because they want to be safe in infringing, to reap where they have not sown, and profit by other people's inventions and business abilities."

The lecturer then passed over to a discussion of the tariff question. There cannot be any doubt that it is due to our tariff laws that a number of new industries have been established in our country. Articles can now be manufactured here, owing to protective duties, the domestic production of which was formerly thought impossible. He quotes as an example the tin-plate industry.

In Dr. Schweitzer's opinion, however, our method of enacting tariff legislation is altogether unreasonable. The questions of dutiability are settled by a committee of the Senate and the House of Representatives, which finally in conference decide upon the context of any bill. "If we had a tariff commission composed of legislators, of prominent business men, of leading experts in the various lines of manufacture, and of men who make the study of national and social economics their specialty, we would get a tariff which would be just and equitable to all interests, and which would give an impetus to our industries greater than other means of stimulation. Such a committee should be permanent and empowered to act in emergencies."

If, for example, the time was ripe to begin the production of a certain article which could not be manufactured here before, interested parties could bring the matter before the committee and have the substance in question taken from the free list and put under protective duty. The author quotes, for example, oxalic acid. A reasonable protective duty levied on oxalic acid from now on would be of the greatest assistance to the American industry.

In every case, the duties levied should be protective, but not prohibitive. The amount of duty is assessed on three different principles—the specific duty, the ad valorem duty, and the compound duty, the latter being partly ad valorem and partly specific. In Dr. Schweitzer's opinion only specific duties should be levied on chemicals. However, it would be wrong to regard tariff laws a panacea for all evils of the industry, especially in chemical manufacturing. If it were so, we would find the most flourishing industry in the highest tariff countries. But this is not so, as shown by the example of Russia, with its high import duties.

"Closely related to the tariff is the inland revenue tax. In our country, chemical manufacture is only affected by the tax levied on alcohol. It cannot be denied that this tax most seriously injures chemical manufacture. Alcohol is practically indispensable in our industry, and, although American chemists, forced by the great expense, introduced substitutes in the form of wood alcohol, acetone and other organic solvents, in some branches of manufacture, alcohol still remains a *sine qua non* in the majority of cases. If we were called upon to give an instance of a "blood tax" we would point out the internal revenue tax on alcohol for manufacturing purposes, and for this reason: sulphuric ether is one of the most important derivatives of grain alcohol, which must necessarily be employed in its manufacture.

"Ether is most extensively employed as an anæsthetic in surgical operations, and the enormous consumption of ether in the United States becomes apparent by the fact that one New York hospital alone used 2900 pounds last year. The price for ether is 70 cents per pound, whereas in Germany the same quality, made from tax-free alcohol, is sold for 7½ cents per pound. Although Germany levies a very heavy internal revenue tax on alcohol as a beverage, it allows tax-free alcohol for manufacturing. It has introduced for this purpose the system of denaturalization, which means rendering the alcohol unfit for drinking by the addition of various ingredients. Above all, wood alcohol and pyridine, a substance derived from the tar obtained in charring bones, are mixed with the alcohol in such a manner that recovery of grain alcohol from the mixture is practically impossible. For uses in the various industries different methods of denaturalization are adopted. Because the ordinary mixture is ill-smelling on account of the presence of pyridine, it cannot be employed for the manufacture of perfumery. Therefore, the wise government allows for this use a different manner of denaturalization which eliminates pyridine, and whenever a manufacturer proves that the ordinary tax-free alcohol is not fit for making his specialties, on account of the presence of these chemicals, another form of denaturalization is devised and permitted. In the same manner, Germany permits the denaturalization of salt, on which it levies a revenue tax when used for eating purposes. As well known, salt is largely employed in the dye-

stuff industry for the precipitation of dyes from their watery solution. Salt is therefore denaturalized by coloring it with dye-stuffs, and it is a curious sight in German factories to see in the yards heaps of blue, yellow, green and red salt which are employed for the precipitation of the corresponding coloring matters."

Owing to the tax on alcohol a number of articles cannot be manufactured here at all, and must be imported. Among them are fulminating powders and fulminates. "It is absolutely imperative for our Government to follow the example of Germany, if we wish to see the manufacture of fine chemicals as flourishing here as it is there."

Dr. Schweitzer finally refers to another class of legislation as a great promoter of chemical industries which at first glance appears to be much more oppressive than beneficial. These are the laws for preventing such nuisances as fouling the air and polluting water courses.

"In the early eighties the municipal authorities of some towns in the zinc mining district of Silesia passed legislation against the escape of sulphurous acid gas from the chimneys of the roasting furnaces of zinc ores. Chemists in the employ of the zinc smelters undertook the task of finding some uses for the generated gas, which at that time was practically valueless. They succeeded in compressing the gas to a liquid on a commercial scale and used it in processes invented by themselves for the manufacture of glue and gelatine. But the supply of gas from the roasting furnaces became soon so enormous that they had to find still other uses. It then occurred to them to attempt the oxidation of sulphurous acid by means of the oxygen of the air for the production of sulphuric acid, a reaction which had been scientifically exploited by the famous chemist Clemens Winkler. Their experiments were successful, and soon they established works where sulphuric acid was manufactured from sulphurous acid gas, which hitherto escaped as a useless by-product, in roasting zinc and iron pyrites, vitiating the air and destroying vegetation. In this manner was born what we call the contact process for the manufacture of sulphuric acid, which, with later improvements by other investigators, revolutionized a branch of chemical industry in which it was generally believed that there was hardly any room for improvement.* In this connection let me add that this contact process is one of the factors which made the synthesis of indigo a commercial success. One of the steps in the process of making this color is the oxidation of naphthalene by means of fuming sulphuric acid, the decomposition of the latter producing sulphurous acid. Instead of allowing the gas to escape it is now treated with the oxygen of the air in the contact process, reconverted into sulphuric acid, which enters again into the circle of the indigo synthesis.

"Another example we find in the starch industries. Until the manufacturers were prevented from running their wastes into rivers they made only starch and products derived therefrom. But when the law prohibited the pollution of water courses they investigated what they formerly called waste, and found that it contained valuable albuminoid matter, which is now utilized as feed; that an oily substance which formerly escaped their notice was present in the waste which could be extracted and employed for the manufacture of soap and glycerine, and by treatment with sulphur could be transformed into a substitute for rubber.

"An interesting example, is also the following: In the preparation of sauerkraut a juice is pressed out from cabbage which contains decomposed vegetable matters, and when run into rivers kills the fish in the water. It was therefore forbidden to pollute water in this manner. Then chemical research established the presence of valuable organic acid in this waste water, and by concentration and filtration a liquor was obtained which proved to be of great value in the textile industries and in the tanning of skins. This liquid is now in the market under the name of 'Vegetalin.'" (Concerning the "sauerkraut industry," Dr. Schweitzer remarks that there are alone on Long Island about twenty factories, each using every season 2,500,000 pounds of cabbage, which furnish 80,000 gallons of juice as a by-product, or 1,500,000 gallons of waste in the Long Island factories alone. Around Chicago and St. Louis there are still larger establishments.)

The author thinks that if there is anything which fosters chemical manufacture in Germany, it is the intelligent cooperation of the government with the manufacturing interests and with the educational elements. "In this respect our strenuous republic has still something to learn from what many of us are apt to consider an effete monarchy."

* In this connection an article in our September issue (page 347) should be of interest.—Ed.

THE MANUFACTURE OF FERRO-ALLOYS IN THE ELECTRIC FURNACE.

By George P. Scholl, Ph. D.

(*Concluded from page 396.*)

The ferro-silicon obtained in the electric furnace comes directly into competition with the alloy made for a long number of years in the blast furnace, running the latter with a very refractory slag and at a very high temperature, and a consequent excessive consumption of fuel. A silicon content of 15 per cent, however, is about the highest which can be reached in the blast furnace, owing to its temperature limits and the infusibilty of the slag. The peculiar adaptability of the electric furnace, however, to various temperature requirements, made it eminently suitable for the production of alloys with a higher silicon content, and products ranging from 25 per cent all the way up to 80 per cent are readily obtained. They are well fused and taken altogether represent a more homogeneous material than that obtained by the old method. Naturally, a considerable amount of missionary work had to be done to get consumers accustomed to the use of the higher grades of alloys, which was all the harder, as the product obtained in the early stages of manufacturing was sometimes disappointing in the results obtained by it. The advantages, however, resulting from their use, are more and more appreciated and their employment will undoubtedly be much extended in the not far distant future. The advantages accompanying the use of the high-grade alloys in the iron and steel industry, have been set forth at some length in Electrochemical Industry, vol. II., page 122, and will therefore not be detailed here. The tendency is toward the employment of the higher grades, corroboration of which, as far as the German steel works are concerned, is furnished by a statement of Dujardin, to the effect that at present the employment of 25 per cent ferro-silicon seems to be completely abandoned by them, the 50 per cent alloy being more and more in demand. From 10 tons in the second half year of 1902, the consumption of the latter alloy increased to about 500 tons in the second half year of 1903, which fact certainly bears testimony to the success which has attended its application in practice. The alloy, owing to its porous structure, is easily gotten into the shape of a coarse powder, of about nut size, and is used as such directly in the ladle. Dujardin also states that the 75 per cent Si alloy is still too expensive to be used for general purposes, but that, when well made, it is easily incorporated into the molten steel, the reaction is very rapid and energetic, and that whenever the day arrives when it is no more expensive per unit of silicon than the 50 per cent alloy, it will be universally preferred.

As far as the manufacture of ferro-silicons, with varying per centages of silicon, is concerned, the energy expended increases, of course, considerably the richer the alloy is in silicon. All things considered, from an economic standpoint, as pointed out by Keller in his Iron and Steel Institute paper (l. c.), the manufacture on a large scale of alloys rich in silicon is cheaper per unit of silicon the

higher the percentage of the latter in the alloy. This is explained by the fact, that in the low-grade alloys the price of the iron is the most important item, while it becomes much less important in the higher alloys, being replaced there by the much cheaper silica. The purity of the product is also greater in the higher alloys, inasmuch as the impurities are almost exclusively introduced by the iron used. Furthermore, the manufacture of the higher alloys demands a greater and more prolonged application of heat, thus favoring the elimination of impurities by volatilization or secondary reactions.

A sort of a scare has lately been created in the mind of the public by the reports of explosions of ferro-silicon made in the electric furnace, while being handled in a warehouse in Liverpool. This occurrence has even been deemed of sufficient importance to be made the subject of papers before the recent meeting of the British Iron and Steel Institute and the Faraday Society. The alloy in question came from Triest and had the following composition: Si = 59.40, Fe = 36.85, Mn = 0.08, Al = 2.73, Ca = 0.14, Mg = 0.17 C = 0.218, S = trace, P = 0.056. It was concluded that the explosions were probably due to the presence of impurities, more particularly the phosphorus, and it was recommended to the manufacturers to in future only use such materials as are free of phosphorus. Prof. Le Chatelier, however, the well-known French metallurgist, pointed ou in the discussion to the paper before the Iron and Steel Institutes, that the theory of the explosions having been caused by an evolution of phosphoretted hydrogen hardly seems plausible, as the percentage of phosphorus as so low, and as its presence is carefully avoided in the manufacture of ferro-silicon, as well as in that of calcium carbide. He believes it much more likely that the explosions are to be attributed to silicuretted hydrogen, one of the modifications of which is spontaneously inflamable. He states that silicide of calcium is unavoidably found at times, when ferro-silicon is manufactured in the same furnace as has been used for the manufacture of calcium carbide, that appreciable masses of it are often present in commercial calcium carbide, and that under the action of acids it instantly yields spontaneously inflammable silicuretted hydrogen. The calcium silicide is not equally distributed throughout the mass, and a batch of ferro-silicon made immediately after a calcium carbide burden, would probably be contaminated. The above opinion of Prof. Le Chatelier appears undoubtedly the correct one, and it seems the casting of doubt on the product of the whole industry was certainly unwarranted, inasmuch as the greater part of the production of some 5000 tons annually is made in furnaces which are not used for carbide.

Ferro-Chromium.

This alloy, like ferro-silicon, was one of the pioneer products of the electric furnace, when the latter was applied to the manufacture of the ferro-alloys, and as outlined above, its manufacture underwent a gradual evolution as far as quality of the product was concerned, after passing through a period of ruinous competition.

The manufacture of the alloy can be carried on either in the blast furnace, the crucible furnace or the electric furnace, and was in former years carried out almost exclusively in the blast furnace. The latter, however, does not furnish an alloy richer in chromium than 30 to 40 per cent, and is probably now entirely out of the race, as the preference among consumers is given to a material containing at least 60 per cent. The manufacture in the crucible furnishes alloys of high percentage, but only small quantities of material can be treated at one time, special and expensive crucibles are required and the impurities contained in the alloy are rather high. The electric furnace is therefore the only means by which alloys of a high percentage of chromium can be manufactured in a sufficiently pure state and in sufficiently large quantities for commercial use. Large quantities of ferro-chromium are manufactured by the aid of electricity, especially in this country, France and Germany, among them rich alloys of very high purity, especially in regard to the amount of carbon, which they contain.

The manufacture of the alloy is carried on in a variety of furnace constructions, from the simple furnace, as used among others by Willson, where the crucible constitutes one of the electrodes to the more complicated forms employed in Europe, where the electrodes do not come into contact with the alloy. Some data on the manufacture of ferro-chromium in this country by the Willson Aluminium Company at Kanawha Falls, W. Va., and Holcomb Rock, Va., are given by Dr. Haber in his report, mentioned above (l. c.). According to him the works at Kanawha Falls use three dynamos of 800 kw. each, those at Holcomb Rock one-third of that power. The ore used is principally Cuban and Turkish chrome iron ore, Canadian and New Caledonian ore being also employed. The Cuban ore has the following composition: Cr_2O_3 = 50 per cent, FeO = 18.57 per cent, Al_2O_3 = 12.44 per cent, MgO = 13.38 per cent, CaO = 2.16 per cent, SiO_2 = 3.82 per cent, S = 0.69 per cent, P = 0.2 per cent. The Turkish ore analyzes: Cr_2O_3 = 52.8 per cent, FeO = 10.24 per cent, Al_2O_3 = 10.48 per cent, MgO = 13.96 per cent, CaO = 2.37 per cent, SiO_2 = 6.95 per cent, S = 0.06 per cent, and Fe_2O_3 = 3.79 per cent. The ferro-chromium obtained shows Cr = 70.96 per cent, Fe = 23.23 per cent, Si = 0.5 per cent, C = 5.21 per cent, P = 0.008 per cent, and S = 0.078 per cent, the consumption of energy being about 10.6 e. h. p. hours per kilogram of the product. Alternating current of 110 volts pressure is used at Kanawha Falls, the current of 22,000 amperes being divided on seven furnaces, all of them crucible furnaces of partly circular, partly square and rectangular cross-section. The outside dimensions of the largest furnace are 120 inches wide, 80 inches long and 60 inches high, the smaller ones being about 60 inches square and 50 inches high. The furnaces are iron boxes, with a very thick lining of pieces of anode carbons, with a tar binder. They are provided with a tapping hole. In a few furnaces the lining constitutes one electrode, while the other electrode is formed by a bar of carbon, which depends vertically into the furnace. Other furnaces have two parallel electrodes, which depend vertically into the crucible and are movable. In this latter form the crucible itself is not connected into the electric circuit. The hanging electrodes are in each case bars of 60 inches in length and 4 x 4 inches cross-section, two bars laying side by side forming one electrode. The iron heads into which these electrodes are fastened, are provided with cooling arrangements by means of water. The carbon lining is stated to be replaced in time totally by the material of the melt, which is constantly produced in the furnace, so that finally the melting takes place in a crucible practically of the same material as that which is melted.

Ferro-silicon and ferro-chromium are made at Livet, according to the report of the Canadian Government Commission sent to France to investigate the possibilities of the electric furnace for the manufacture of iron (Electrochemical Industry, Vol. II., page 180), in a furnace closely resembling the one illustrated above, except that the base of each shaft is formed by a carbon block, which blocks are in electrical communication on the outside of the furnace by means of copper bars. The carbon electrodes which depend into each shaft are 28 inches in diameter and 53 inches long.

According to Pitaral, the works manufacturing ferro-chromium in France are the following: Société Electrometallurgique Française at La Praz, Société La Néo-Métallurgie at Giffre, Société Anonyme Electrometallurgique at Albertville, Keller, Leleux & Co. at Livet, Société Eléctrometallurgique de Saint-Béron at Saint-Béron, Ch. Betrolus at Bellegarde and Rochette Frères at Epierre. From the statement of Dujardin mentioned above, it appears that the products of the French works are somewhat lower in carbon than that which is given in the analysis of Wilson's product quoted above. Within recent

times a soft ferro-chromium (ferro-chrome doux) has been put on the market, especially by the Société la Néo-Métallurgie, containing carbon as low as .25 per cent. This latter alloy is much appreciated, but on account of its high price its use is as yet rather limited. Its price is quoted at Paris as 4 francs per kilogram, based on a percentage of 60 of chromium and 0.4 to 1 per cent of carbon, with increase of 0.06 francs for every unit of chromium above 60 per cent. The Société La Néo-Métallurgie has also patented a ferro-chromo-nickel alloy of the following per centage: 16-38 per cent Fe, 5 to 60 per cent Ni and 24 to 57 per cent Cr. The total combined amount of the three metals is 98.80 to 99.50 per cent, and the alloy contains from 0.30 to 0.80 per cent of carbon, the rest being made up of silicon, sulphur and phosphorous. A ferro-chromo-silicon, containing 50 per cent of chromium, 8 to 10 per cent of silicon, 38 per cent of iron and 2 per cent of carbon is also quoted regularly at 650 francs per ton.

FERRO-MANGANESE.

Ferro-Manganese is another one of the alloys, which were the first ones to be made in the electric furnace, and the hopes entertained about its manufacture were rather sanguine. These hopes were, however, doomed to disappointment, and at the present time, according to Pitaval (*Journal de l'Electrolyse*, page 4, 1904) the manufacture of ferro-manganese in the electrice furnace has been abandoned in France. A great deal of trouble has been experienced in the manufacture of this alloy in the electric furnace, due principally to the absolute necessity of avoiding too high a temperature with consequent great volatilization of the manganese and very low yield. The blast furnace, which has been so effectively attacked by the electric furnace, as far as ferro-chromium and ferro-silicon were concerned, still reigns supreme in the field of ferro-manganese, on account of the more economic production possible. A silico spiegel, however, with 20 to 25 per cent of silicon and 55 to 40 per cent of manganese, or 50 per cent of silicon and 30 per cent of manganese is reported to be manufactured by Keller, Leleux and Co. at Livet. A mangano silicon, with about 76 per cent of manganese, about 21 per cent of silicon, about 1 per cent of iron and about .95 per cent of carbon is also quoted.

FERRO-TUNGSTEN.

The reduction of this alloy cannot be performed in the blast furnace on account of the high temperature necessary. The alloy made in the electric furnace by reducing tungsten concentrates has to compete against the metallic tungsten in powdered form, as it is furnished by the chemical works. It seems that its manufacture is principally carried out at the Albertville works, the manager of which, M. Girod, claims to have melted an alloy of 85 per cent tungsten in his furnace described by Bennie in ELECTROCHEMICAL INDUSTRY, Vol. II., page 309. The purity of the product in regard to the contents of carbon, has been much improved. In Germany it is said to be little used as yet, as the tool steel manufacturers prefer the powder. Nevertheless, the use of the alloy is likely to increase, as it is claimed that the alloy has the following advantages: 1. It alloys easily with the steel and almost quantitatively, without loss, while the metallic powder oxidizes more easily and is very refractory. 2. A good ferro-tungsten obtained in the electric furnace contains generally less impurities than the powder. 3. The unit of tungsten in the ferro-alloy costs much less than that in the powder. Alloys made in the electric furnace showed the following composition: Tungsten, 70-75 per cent, carbon 2-3 per cent, sulphur and phosphorous less than 0.02 per cent; tungsten about 80 per cent, carbon 1.5-2 per cent; tungsten 80 per cent, carbon 0.52 per cent, silicon 0.1-0.2 per cent, sulphur and phosphorous almost nil, the total impurities less than 0.75 per cent. The latter alloy is, of course, a very fine product. The 70 to 80 per cent alloy is quoted in Paris at 4 francs per unit.

The analysis of ferro-tungsten manufactured at Kanawha Falls is given by Haber (l. c.) as 60.92 per cent of tungsten, 28.38 per cent of iron, 0.566 per cent of silicon, and 2.36 per cent of chromium. Rossi (*Mineral Industry*, 1903, page 695), dealing with his method of the reduction of oxides by aluminium in the electric furnace, states that for the manufacture of ferro-tungsten he used concentrates of the following composition: Tungstic acid 69.86 per cent, silica 5.04 per cent, ferrous oxide 20.25 per cent, equivalent to 55.20 per cent of metallic tungsten and 15.73 per cent metallic iron. A furnace of the old Siemens type, consisting of graphite blocks with a central cavity, serving as cathode and a vertical, movable carbon anode, was charged with ingots, scraps, etc., of aluminium in sufficient quantity to reduce the iron and the tungsten. The current was then allowed to melt the aluminium and the oxides were introduced into the molten metal. The reaction began at once, the iron being first reduced to metal and forming a bath in which the tungsten dissolved. Abundant fumes of alumina in a dense white cloud were given off as the reaction proceeded, while the larger portion of the alumina formed a sort of slag on the surface of the bath. The current was increased towards the end of the reaction for a few minutes and the metal was then cast. With the expenditure of about 11 hp. of current, 646 pounds of an alloy containing 75.91 per cent of tungsten, 21.47 per cent of iron, 161 per cent of silicon, 0.08 per cent of sulphur, 0.90 per cent of carbon and no aluminium are stated to have been made in 30 minutes.

FERRO-VANADIUM.

There is still a good deal of controversy about the use of this alloy in metallurgical circles, as the influence of vanadium on iron and steel products has not been definitely ascertained yet. Ferro-vanadium alloys, when they were first manufactured were far from pure, inasmuch as they contained about 5 to 10 per cent of aluminium and 2 to 3 per cent of carbon. It has been possible, however, lately to put products on the market, the analysis of which showed 26.25 per cent of vanadium, 73 per cent of iron, 0.40 per cent of aluminium, traces of carbon and 1.0 per cent of silicon. The prices for the 25 per cent alloy, guaranteed free from carbon, as given some time ago by the Syndicat International du Vanadium at Paris, were 20 francs per kilogram in quantities from 1 to 20 kilos, going down to 16 francs per kilogram for ton lots and above. A ferro-silico vanadium has also been prepared in somewhat larger quantities, which contained 30 per cent of vanadium, 10 per cent of silicon and 2 per cent of carbon. It is claimed that on account of the silicon which it contains it has the great advantage to elevate the temperature of the vanadium which it accompanies into the bath of the metal, with which it is to be alloyed, and to aid the smallest quantities of the vanadium to distribute themselves evenly through the bath. The silicon besides has the advantage of preventing high percentages of carbon. Gin, the well-known French electrometallurgist, has lately patented an electrolytic method for the production of ferro-vanadium, which is described by the writer in ELECTROCHEMICAL INDUSTRY, Vol. II., page 324. It depends upon the electrolysis of vanadium fluoride dissolved in calcium fluoride, the cathode being a bath of liquid iron, and the anode a specially prepared and compressed mixture of vanadium trioxide and carbon. The fluorine produced by the electrolysis of the vanadium fluoride dissolves the vanadium compound of the anode and regenerates the electrolyte, while the vanadium alloys with the iron. Gin states that for alloys with more than 25 per cent of vanadium the cathode section should be appreciably less than the active anode surface. Good results and a sufficiently liquid bath are stated to have been obtained with a medium current density of two amperes per square cm. of active anode surface, six amperes per square cm. cathode surface, and between eleven and twelve volts pressure. Data as to the working of the process on a large scale in practice are not available.

FERRO-MOLYBDENUM.

This alloy is made at the Albertville works, and at the

works of the Néo-Métallurgie Society at Rochefort sur Mayenne. It is said to be little used in Germany, the consumers preferring the metal. The alloy most generally used contains about 60 per cent of molybdenum, the prices at works being quoted as 19 francs per kilogram of molybdenum for the 60 to 80 per cent molybdenum alloy, containing two to three per cent of carbon. The sulphur and the phosphorous are each below 0.3 per cent. Rossi states that by the use of his process he has obtained the alloy free from carbon.

Ferro-Titanium.

It is unnecessary to dwell on the manufacture of this alloy in the electric furnace, inasmuch as it has been discussed at considerable detail by Rossi in Electrochemical Industry, Vol. I., page 523, who has made a special study of the alloy for a number of years, and has contributed much to our knowledge on the subject.

* * * *

In the foregoing the uses of the different ferro-alloys dealt with and the properties which they impart to the products with which they are incorporated have not been considered, as they are briefly and concisely stated in an extended extract from an article by Rossi in the *Iron Age* of November 12, 1903, in the Synopsis of Articles in Other Journals, Electrochemical Industry, Vol. I., page 583.

In concluding this brief review it is hardly necessary, in view of the facts pointed out above, to assert that the electric furnace has established its right to be considered an important adjunct in metallurgical practice and that the time is over definitely when it could be looked upon as a mere laboratory toy of doubtful practical ability. The high temperature which can be obtained in it, the ease with which it can be regulated, and the consequent possibility of successfully handling refractory substances beyond the limit of ordinary furnaces, are advantages which are making themselves felt more and more. Signs are everywhere apparent which indicate that the time is fast approaching when it will be utilized to a much larger extent in metallurgy than at present. All honor is therefore due to the pioneers in the manufacture of the ferro-alloys, who, recognizing its possibilities, labored hard and in the face of serious and discouraging obstacles, to demonstrate its practical applicability.

WILHELM OSTWALD.

In a review of P. Walden's biography of Wilhelm Ostwald, Dr. Wilder D. Bancroft writes in the October issue of the *Journal of Physical Chemistry* as follows:

"The change in the scientific status of Ostwald has been a remarkable one. In 1890 the electrolytic dissociation was fighting for recognition. Nernst's paper on the voltaic cell had been published, but had attracted very little attention. The general feeling of chemists toward Ostwald was that he was an able man who was wasting his talents. Some went so far as to deny his claim to being a chemist. Any idea held by Ostwald was *per se* an object of suspicion. To-day the opposition to the electrolytic dissociation theory comes from those who believe that it has outlived its usefulness. Ostwald is recognized as one of the leading chemists of the world, and any opinion of his is promptly accepted as dogma by a large enthusiastic following.

"Ostwald is essentially a leader of men. The theory of solutions was furnished by Van't Hoff; the theory of electrolytic dissociation by Arrhenius; the theory of the voltaic cell by Nernst. Not one of these three important generalizations is due to Ostwald; but he has taken all three, developed them and brought them to recognition and acceptance as no one else could have done. Nernst's theory of the voltaic cell lay dead until Ostwald took it up. Everything about the theory of electrolytic dissociation except the formulation is due to Ostwald. No one believes that Arrhenius could have overcome the opposition of the chemists. It was Ostwald who brought the theory of osmotic pressure to the front. The work of the Beckmann, done in Ostwald's laboratory, made the testing of the theory a simple matter, while Ostwald himself lost no opportunity to impress people with the importance of the theory.

"It is a leader rather than as a pioneer that we must consider Ostwald. The pioneer discovers the new land; but his discovery will come to nothing if the people do not follow him and take possession of the country. The pioneer is independent of the world. He must have a clear insight and courage. The leader must not be too far ahead of his followers. He must be working toward the same goal as they and be able to help them forward. He is handicapped by the fact that he cannot move faster than the army can follow him, but this is more than balanced by the fact that every advance is held.

"To some it has seemed that Ostwald's point of view has not changed in the last ten years as much as it should have done. This may or may not be true. It is true, however, that the chemical world has been brought up to Ostwald's position by Ostwald; and there are a few who hope and believe that Ostwald's Faraday lecture is the signal for a new and rapid advance. It may well be so. For seventeen years, the bulk of the work in physical chemistry has been devoted to dilute solutions, largely as a result of Ostwald's personal influence. So great is his influence that he could change this inside of a twelve-month. Ostwald exerts a tremendous power in the chemical world to-day. If he will devote himself to chemistry instead of to philosophy, and will throw his influence in favor of progress, there is before him another era of triumphant achievement, compared to which the results of the past decade will appear trivial. If he does not do this, the world will still move on, though not so rapidly as might have been the case."

Prof. Ostwald's Faraday lecture, to which reference is made above, deals with the same ideas which were brought forward by him in his Bunsen Society paper on hylotropy abstracted on page 361 of our September issue.

SOME EXAMPLES OF CATALYTIC ACTION IN ELECTROLYSIS.

By C. J. Thatcher, Ph. D.

It has been emphasized in this and other journals recently, that in all electrolyses on polarizable electrodes it is advantageous to very carefully control the e. m. f., not only of the entire cell, but more especially of the anode or cathode, or both, as the case may be. This subject is not without a bearing on commercial electrolyses, for wherever secondary and usually undesirable electrode processes can occur—and that is quite generally—their velocity will be influenced among other things by the e. m. f. of the concerned electrode. For this reason, the control of the e. m. f. of polarization is an important factor in increasing current yield.

Among other papers bearing on this subject is that recently presented at the International Electrical Congress by Prof. W. Ostwald, of Leipzig University, and which was published in the October number of this journal. Prof. Ostwald draws attention there to the fact that with increasing e. m. f. applied to the terminals of the cell those ionic processes will first occur which require the smallest difference of potential. He also points out some of the factors, other than applied e. m. f., which will influence the electrode e. m. f. or polarization. Of these ionic concentration, diffusion rates, induced and purely chemical reactions and catalytic influences may be mentioned.

It is desired here to treat especially of catalytic influences in electrode processes, and to illustrate them by some concrete examples. Most of those to be mentioned were observed during the course of an extended investigation of an electrolytic oxidation process made in Prof. Ostwald's laboratory in Leip-

zig in the years 1901-1903 and published in the *Zeit. f. Phys. Chemie*.[1] During this research certain observed phenomena impelled the author to contend that catalytic influences played an important part in this and other electrode processes. And by means to be given in part here, he was able to verify this theory and to bring to Prof. Ostwald's attention the ideas of catalytic electrode influences to which he has given expression in the above-mentioned paper, and which Prof. Luther and his scholars are now further investigating.

It is unnecessary to review the general aspects of the subject, for Prof. Ostwald has shown in his paper how catalytic agents may be expected to act in electrode processes. He has also pointed out in what direction the idea may be applied practically; that is, namely, first, in synthetic work to retard undesirable reactions by the use of negative catalyzers, or to accelerate such as are desired with positive catalyzers; and, secondly, to analyze electrode porcesses in order to arrive at the mechanism of any process under investigation.

These two applications are well illustrated by the effect of catalytic agents in the oxidation of sodium thiosulphate solutions on platinized platinum anodes, which was investigated by the author in the before-mentioned research. For the sake of clearness it will be necessary to state here briefly some of the results of this investigation. It was found that solutions of C. P. recrystallized $Na_2S_2O_3$ in purest redistilled water are very slightly alkaline—as is not generally known. This alkalinity can be ascribed to several causes which it will not be necessary to give here. As long as this weak alkalinity of the solution was preserved, the result of the electrolytic oxydation was the formation of sodium tetrathionate—$Na_2S_4O_6$—in almost theoretical quantities. In this case the solution remained very nearly neutral throughout the electrolysis. The tetrathionate ion itself was not further oxidizable at any anodic polarization, however high. But in solutions which contained any considerable amount of alkali, it was established that the S_4O_6 ion was slowly decomposed by hydrolysis forming among other substances trithionate, and that this was then further oxidized to sulphate. In acid solutions, on the other hand, the S_4O_6 ion was slowly decomposed by hydrolysis forming among sulphite, which latter was oxidized at once to sulphate. The primary electrode process in thiosulphate oxidation proceeds undisturbed therefore only in very weakly alkaline solutions, and any of a number of conditions previously unrecognized sufficed to cause the predominance of the secondary processes.

In the investigation of the *mechanism* of the oxidation process, many indications pointed to the fact that water was decomposed at the anode. The oxidation potential was between —0.70 and —0.90 volts, and below the commonly accepted anodic decomposition potential of water. Notwithstanding this it seemed probable that oxygen or some combination of it, with hydrogen was liberated at the anode by the discharge of the hydroxyl or bivalent oxygen ion. In proving this theory the author made recourse to the action of negative catalyzers, such as are designated as poisons. It was natural to suppose that if oxygen or some active oxidizing substance was liberated on the anode the finely divided platinum black of the electrode surface would act catalytically on the process by which it oxidized the S_2O_3 ion. Now it is firmly established that poisons, *i. e.*, substances which have a poisonous effect on the human system, also exert an inhibitory influence on reactions in which platinum black acts catalytically.[2]

If, therefore, oxygen was liberated on the anode as the primary electrode process, and if the platinized electrode surface acted catalytically on the secondary, purely chemical reaction, whereby the S_2O_3 ion was oxidized, the addition of small amounts of "poisons" would retard this reaction, and should effect the potential of thiosulphate solutions, and the polarization of the anode in their electrolysis.

Numerous and diverse experiments showed that this actually occurred. The poison mostly used was mercuric cyanide, selected because it was practically non-dissociated, and of great inhibitory power.[3] In Fig. 1 the effect of very small quantities of $Hg(CN)_2$ on the polarization of the anode in the process $S_2O_3'' \rightarrow S_4O_6''$ is clearly shown. For the details of this and later-to-be-mentioned experiment the reader is referred to the original article in the *Zeit f. Phys. Chem.* It

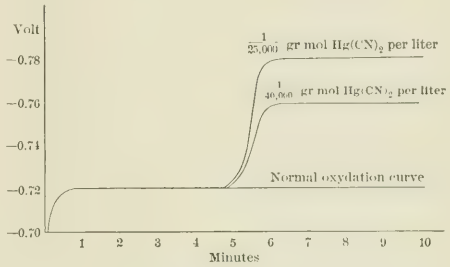


FIG. 1.—EFFECT OF MERCURIC CYANIDE ON OXIDATION POTENTIAL OF $Na_2S_2O_3$ SOLUTION.

suffices to state here that the polarization of a platinized platinum anode on which S_2O_3 ion was being oxidized to S_4O_6 ion increased 0.04 volt almost instantaneously on the addition of a drop of $Hg(CN)_2$ of sufficient strength to make its concentration about one grammolecule in 40,000 liters of $Na_2S_2O_3$ solution. A second experiment in which the $Hg(CN)_2$ was added in the proportion of 1 grammolecule in 25,000 liters, caused an increase of about 0.06 volt in the e. m. f. of polarization. Without these additions the anode polarization remained nearly constant for several hours of continued electrolysis.

That $Hg(CN)_2$ really does effect the rate of oxidation of $Na_2S_2O_3$ solutions by oxygen gas on platinized platinum is

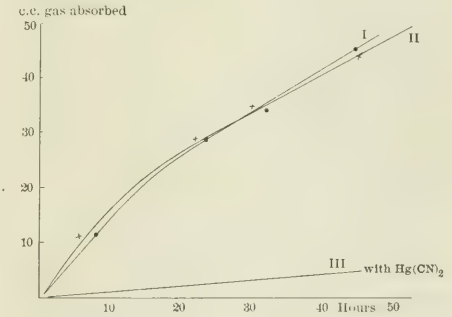


FIG. 2.—EFFECT OF MERCURIC CYANIDE ON OXIDATION OF $Na_2S_2O_3$ SOLUTION BY OXYGEN.

shown graphically in Fig. 2. Curves I. and II. give the number of c. c. of oxygen gas absorbed per unit of time by dilute $Na_2S_2O_3$ solutions containing a piece of platinized platinum, in two confirmatory experiments. Curve III. shows that on the addition of a very small amount of $Hg(CN)_2$ the velocity of the oxidation was greatly retarded. Other experiments, not illustrated, established the fact that the velocity of the oxidation of S_2O_3 ion by oxygen gas was extremely slow *without* platinum.

These facts make it certain, therefore, that in the electrolytic oxidation of thiosulphates oxygen or some other active oxidizing substance (*e. g.*, possibly H_2O_2) is formed primarily at the anode. This theory is still further supported by the pronounced effect of $Hg(CN)_2$ and other

[1] Zeit. f. phys. Chem., vol. 47, page 641

[2] See Bredig & Ikeda, Zeit. f. phys. Chem., vol 37, page 1, and others.

[3] Bredig & Ikeda, loc. cit., page 58.

"poisons" on the potential of $Na_2S_2O_3$ — $Na_2S_4O_6$ solutions, and by other observed phenomena. It was thus established that this oxidation is not a primary, purely electrolytic process according to the equation,

$$2S_2O_3'' + 2F = S_4O_6'' \quad (1)$$

where F means the positive electric charge of a univalent gramion, but rather that it is secondary, and that the mechanism of the reaction is somewhat like

$$O'' + 2F = \tfrac{1}{2}O_2 \quad (2)$$

$$2S_2O_3'' + \tfrac{1}{2}O_2 = S_4O_6'' + O'' \quad (3)$$

The author was able in this way to demonstrate convincingly that the surface of electrodes may act catalytically in electrolyses, and to point out, to a great degree of certitude, the probable mechanism of a complicated electrode process. We thus have an example of the value of catalytic agents in the *analysis* of electrode processes.

The practical bearing of this subject and the advantage of a similar intimate understanding of the mechanism of the electrode process in the development of commercial electrolytic processes may be illustrated by analogy. Here, in the case of $Na_2S_2O_3$ oxidation was an extremely sensitive electrolytic process, one which was practically uncontrollable until its mechanism was understood, at least to some degree. But this having been accomplished, it followed logically, for reasons which it will be impossible to give briefly here, that in

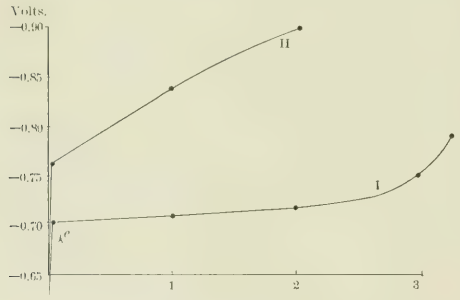


FIG. 3.—EFFECT OF IODINE ION ON POTENTIAL OF $Na_2S_2O_3$ OXIDATION. (THE ABSCISSÆ REPRESENT HOURS.)

order to exclude the undesirable secondary reactions, and to obtain a nearly theoretical yield of $Na_2S_4O_6$ it would be necessary to keep the concentration of the oxygen gas in the electrode as low as possible. One way to accomplish this was to accelerate reaction (3) above. This was accomplished handily by the addition of small amounts of potassium iodide to the solution. The velocity of the reaction

$$2I' + \tfrac{1}{2}O_2 + H_2O = I_2 + 2OH' \quad (4)$$

in the presence of platinum black is much greater than the similar oxidation of the S_2O_3 ion. The velocity of the reaction

$$2S_2O_3'' + I_2 = S_4O_6'' + 2I' \quad (5)$$

is very great also. In the presence of iodides, oxygen, when formed at the anode, cannot attain any great concentration, therefore, before iodine is liberated and the slight amount of previously discharged OH ion is replaced according to reaction (4)

But the iodine oxidizes S_2O_3 ion to S_4O_6 ion almost instantaneously reforming two iodine ions (reaction (5)). The combined effect of these reactions is that after the passage of the current the S_2O_3'' is oxidized to S_4O_6'', while the OH' and I' concentrations are unchanged.

The effect of one grammolecule of KI per 1600 liters on the oxidation potential of $\frac{n}{10}$ $Na_2S_2O_3$ solution is shown in Fig. 3, Curve I. The oxidation began at about —0.70 volt, and increased very slowly, until the oxidation of S_2O_3'' was nearly complete. The yield of tetrathionate was about 98½ per cent of the theoretical, and no acid or sulphate was formed. Under the same conditions without the use of KI the oxidation began at about — 0.76 volt and increased very rapidly, as shown in Curve II. The solution quickly became acid, and much sulphur was precipitated and sulphate formed. Small amounts of iodides therefore enable us to prepare $Na_2S_4O_6$ synthetically in solution by the electrolytic oxidation of $Na_2S_2O_3$, although this process otherwise is extraordinarily difficult to control. We have here an example of the value of catalytic agents in electrolytic *synthetic* work.

It may be argued that this is not a true catalytic action, because the manner in which the iodine ion works can be explained. On the other hand, it *is* catalytic in the sense that the actual concentration of the iodine ion is not appreciably changed at any time during the process, and superficially viewed it appears merely by its presence to accelerate a reaction which can accur, otherwise, of itself. In this sense it corresponds to the commonly accepted definition of a catalyzer.

A number of other pronounced and previously unknown catalytic and electrode effects were discovered which cannot be dwelt on now. They are operative, not only in the oxidation of the S_2O_3 ion, but in many other electrode processes. In this connection may be mentioned the work of Luther and Brislee on the electrolysis of chloride solutions. Subsequent to the author's discovery and proof of the secondary nature of the S_2O_3 ion oxidation, they found that the chloride electrolysis was also secondary, which they[4] were able to prove in part by use of $Hg(CN)_2$.

To sum up, there has been illustrated here: First, the use of catalytic agents in *analyzing* electrode process; secondly, by analogy, the practical use to which such agents may be put in *synthetic* electrolyses. It has also been pointed out that the *electrode metal* or *substance* may also act catalytically, as well as dissolved substances or the ions of dissociated electrolytes, which Prof. Ostwald has mentioned. Similar catalytic effects due to electrode surfaces or to impurities of the solution are present quite generally in electrolyses. They are not confined to the oxidation of anions, but are operative also in the reduction of anions on cathodes, either of platinum, or of the baser metals, as the author has lately found. They may be expected to extend also to the electrolytic deposition of metals, as Prof. Ostwald has pointed out. It is certain, therefore, that careful investigation and control of electrode processes with regard to catalytic influences will be of much service in increasing current yield in commercial electrolyses, and in developing and making of economic value many that are not now practicable.

Correspondence.

REFRACTORY MATERIALS.

To the Editor of Electrochemical Industry:

Sir—Since you kindly allowed me, during my recent stay in New York, to read over the proofs of Mr. FitzGerald's article on refractory materials in electrical resistance furnaces, I like to make the follow remarks with respect to this subject. I am specially interested in it, because, about two years ago I conducted some original experiments in Maroker, Norway, with a view to getting a new highly refractory material. The furnaces were of the Siemens & Halske type, built for the manufacture of carbide of calcium on the intermittent system, and they were supplied by current from two 900-kw. three-phase generators, driven by a water turbine. The material on which I worked was native magnesite brought from Southern India. This material is found in its native condition in a

[4] Luther & Brislee, Zeit. f. phys. Chem., vol. 45, page 230.

very pure state, and it has been used for generations by the natives for plastering walls of their houses and also as a refractory material.

As you are aware, a good deal of it has been mined in Southern Europe and made into bricks by being shrunk in the rotary kiln. The heat, however, from this kiln is not sufficient to wholly shrink the material or to drive off the lime and iron which is usually present. In the electric furnace I found that it was possible to pass it down the chutes in just the same way as the raw materials when making carbide of calcium, and that when once the arc was started it could be fed in at a fairly rapid rate and completely shrunk, that is to say all the CO_2 being driven off without the assistance of any carbon or other material.

I made in chunks of about 15 inches cube, and after taking it out of the furnace I had considerable difficulty in breaking it with a sledge hammer. The material had a fine crystalline structure with a beautiful iridescent color, and it had evidently been in a molten condition. I made several attempts to mould the natural half-shrunk material into bricks and thoroughly treat these in the electric furnace, but with poor success.

On returning to England in November, 1902, I found my friend, Mr. Deighton, of the Hunslett Corrugated Tube Works, trying carborundum as a wash on the surface of the refractory blocks through which the water gas flame passes when heating the steel tubes. I showed him the electrically shrunk magnesite which I had made and suggested that if carborundum was good, then it was probable that this magnesite material would be even better, and considerably cheaper. As a matter of fact, it has been used as a furnace wash with considerable success. I am not able to say, of course, whether it is any better or cheaper than the siloxicon or other refractory materials which Mr. FitzGerald mentions in his most interesting article. I know of no more important subject at a moment in the electro-metallurgical practice than this question of getting a really satisfactory refractory lining. E. Kilburn Scott.

London, England.

To the Editor of Electrochemical Industry:

Sir—There are a few remarks to be made on Mr. E. Kilburn Scott's letter which may be of interest.

Engels, in one of his patents (U. S. Patent 734,457, July 21, 1903) proposes to make a mixture of carborundum (crystalline silicon carbide) and a binding material, and then to apply this mixture in the wet state to fire brick, thus forming a refractory coating.

Tone refers to the use of "carborundum fire sand," one of the substances I have called "silico-carbides," as a wash on fire brick:

"A very useful mortar can be made from carborundum fire-sand by mixing with it from 30 to 50 per cent of No. 1 fire clay. * * * When thinned down with water, it can be used as a wash or paint on the face of the fire brick, protecting them from the action of the fuel and the heated gases. When applied in this way to the silica lining of the Schwarz furnace, the application being made daily, or two or three times weekly, it has been found possible to obtain a life of 1000 heats without relining." (*The Foundry*, August, 1904.)

Presumably, Mr. Scott proposes to use the electrically shrunk magnesite in the same way; but I can say positively that this substance is not as refractory as the silico-carbides, or carborundum. A few days go Mr. Bennie and I built a furnace in which we used some magnesite for part of the lining. The temperature at the inner surface of the magnesite lining was well below that of the formation of crystalline silicon carbide, but above that of the formation of the silico-carbides. The heat lasted about eight hours, and the magnesite lining, which was about 4 cm. thick, was completely fused.

It seems, therefore, probable that while Mr. E. Kilburn Scott's electrically shrunk magnesite might be most valuable for the highest temperatures attainable in gas furnaces, it would not be of much use at temperatures which are relatively low when dealing with electrical resistance furnaces.

Unfortunately, there exists at present some confusion of terms when speaking of "high," "medium" or "low" temperatures. The use of electric furnace temperatures may practically be said to begin where combustion furnace temperatures leave off, so that a temperature which may be called "high" when referring to gas furnaces would be called "low" when working with electrical resistance furnaces.

Francis A. J. FitzGerald.

FitzGerald and Bennie Laboratories,
Niagara Falls, New York.

THE EDUCATION OF AN ELECTROCHEMIST.

To the Editor of Electrochemical Industry:

Sir—The letter of Mr. W. M. Sanders, which appeared in Electrochemical Industry for July apropos of Mr. Herreshoff's paper in the May issue, is interesting, stimulating and suggestive. For several reasons this subject is most germane to the question of industrial development of electrochemistry. Indeed, education considered broadly and from all points of view is the problem of the modern state; and in each branch does the future of that branch depend on the recruits called to fill up vacancies in the ranks. Happily, in chemical engineering, to-day, vacancies are caused by rapid expansion of the industry, and not by death. If the Duke of Wellington said that "the battle of Waterloo was won on the playgrounds of Eton," so too, it may be said that the metallurgical triumphs of the future are being won in the laboratories of our colleges and technical schools.

Another ground for discussing the question of the training of a chemical engineer in this journal, is that in the observation of the writer, the electrochemist should be first a chemical engineer and should hold his electrochemical knowledge as a reserve force. In the domain of metallurgy, the electrometallurgist is doubly valuable, if his electrical knowledge is supplemented by an understanding of the capabilities of coal fired furnace, etc.

The reason for this is found in the fact that every electrochemical process (and also every electrometallurgical process) is dovetailed into a process that makes use of old reactions. Besides any electrical process uses largely the engineering practice of the profession that dates from the time when electricity started with the frictional machine and stopped with the voltaic cell. Accordingly, the apparatus and expedients of the older profession are valuable to-day in applying the new agent.

As it is necessary for the electrochemist to unite two professions, his education should be broad and liberal. The four years of a college or technical school should be supplemented by two or three years of graduate work even at a pecuniary sacrifice. Repeating the line of argument given generally in the preceding paragraph, the electrochemist should have a training to fit him for the various duties he will be called upon to fill. He should first have a knowledge of the experimental data and the principles of physical chemistry in general, and electrochemistry in particular. Secondly, he should have a knowledge of the present status of chemical and metallurgical engineering. Thirdly, he should have a trained mind, keen to grasp the essence of the problem, to analyze it, and to form his analysis to synthesize a successful course of action.

This last should be the goal of any system of education. Naturally, it is hard to attain. A legal training would be in valuable for this purpose. But a proper pedagogy would effect this result and at the same time give details of knowledge that would not be a useless appendage later. This ability is most manifest in the trained legal mind. Consider, for instance, the decision of Judge Buffington, of Pittsburg, in the

case of the Carnegie Steel Co. vs. the Cambria Steel Co., litigating as to the Jones "Mixer." It is probable that before the trial the Judge knew but little of essential features of the "direct" steel process. But on hearing the arguments of both sides, he brought out in his decision (lately upheld by the Supreme Court) the distinguishing points that were "novel and useful." Another instance comes to the mind of the writer, where the lawyers for one side read, studied and talked with their own experts until on the day of the trial they actually seemed to know more than the experts of either side. Such is the ability of a legally-trained mind.

This is a broad age, and it requires a broad education for it. In later life it is only too easy to fall into a rut—and only too hard to get out of a rut. General principles are difficult to grasp at first. The experience of a special case best drives home the generalization. General principles are still harder to apply. But in spite of all, no course of education should be considered that does not teach in some manner general principles and the means of apply them. Such a training will produce out of good mental raw material the finished product—a trained mind.

When the general principles of the science have been inculcated, then the specilization should be taken up. The specialized study should be such as to improve the general principles previously taught. The course of study should be, if possible, six or seven years. It is a matter of regret to many Americans that the American technical schools attempt "to force their students under glass." Or to subject the metaphor to violent change, applied science must not be fed to the "infant" on the "Mellon's Food" principle. Such a method in actual life does not produce the sturdy specimens, as does the prehistoric way of feeding.

Exactly how far the classical studies should be forced on the youth is a question for pedagogues to decide. Certainly, a mathematical mind has often a distaste for the classics. But psychology and the history of philosophy are requisites for a certain quality of mental fibre. Latin and Greek are not essential to culture, but they give by their clear-cut, concise grammar and the definite style of the classical authors a basis for expression in the more flexible English. An ability to put his ideas (if he has any) into suitable form, is not valueless to any engineer when he is called upon to report on a technical proposition. Constant training in English will perfect his style and make it the vehicle for his thoughts.

Of direct bearing on his later work is a knowledge of physical chemistry and chemical thermodynamics. The value of physical chemistry to the practical man is as marked as is the lack of knowledge on the part of most of them of its simplest principles. For instance, in the transactions of many scientific societies, the fallacy of Berthelot's principle of maximum heat as determining the direction of reaction is uncomplimentarily uncommon. The ignorance of the fact that the capacity of the system for doing external work nullifies the first factor and makes the law only a "half-truth." One would think that an 85-foot blast furnace, making five or six hundred tons of iron contrary to this law a day, would refute the mistaken notion. It should be a *large* argument against it.

In the study of physical chemistry, systematic experimenting will teach not only the laws, but expose the facts on which these laws are based. Thus, the embryonic electrochemist should have a course in physico-chemical measurements. This has a definite application to large-scale work. For instance, in roasting a sulphide ore, the velocity of roasting should be proportional to the cube of the oxygen-pressure on the surface of each particle of ore. So direct are the tenets of the science on practical operation of plants.

Next, this knowledge of theory and experimentation should be applied to some technical proposition. For instance, the researches of Prof. Howe and Mr. Bradford on the Ziervogel process gave as a result of a short research (but a research most brilliantly conceived and most exactly executed) such a knowledge of the temperature limits of the reactions as to enable a metallurgist to operate the process without skilled labor. The process had been brought to the present efficient stage (as at the Argo smelter of Denver) by many years of labor and patent endeavor, by the "hit-miss-and-try-again method."

Cheops built his pyramid by the labor of millions of men-days with wooden levers, cribbing and ropes. The Panama Canal will be built by steam shovels, dredges and modern machinery. The results are equally great, but the method of this century is relentlessly efficient and short. The comparison can be carried to the process as worked out by the Geheimrath von Ziervogel in 1840 odd, and developed in 1902 in the laboratory of the Columbia School of Mines.

Besides this training on the broad lines, some purely technical training is necessary. The electrochemist must understand something of electrical engineering and of mechanical engineering. If he is to enter the chemical side he should know something of the chemical industry; if he is to take up the metallurgical side he should be trained in metallurgy. He must know the calculus. He must know mineralogy. He must know geology. But his knowledge can be somewhat superficial in those lines (in fact, from the nature of the human mind, it must be) and provided he knows physical chemistry with an actve, critical mind, he will have more than an equal chance to succeed. Needless to say, he should read the technical journals, such as the Electrochemical Industry."

After the electrochemist has had his training broad and specialized along the lines indicated above, he may enter as a freshman into the world—the university of hard work. Here he is just as green a freshman as he was when he entered the university years ago. He has his enthusiasm and energy. The older men have on the average lost those youthful traits. They have the experience. The rare example who retains his enthusiasm with the years is of the stamp of "young-old men" so happily termed by Prof. W. James. The young man is judged by his results, sometimes wrongly, but generally the world judges right.

He can do no better than follow the advice of a famous German technical professor—"See all the factories you can." It might be well to work at one plant for a year or so and then change. In the interregnum he should see at least a hundred million dollars worth of plants. He will learn in his talks with superintendents, with foremen, with workmen who talk broken English. He will see things tried by older and wiser heads than his, with looked-for success sometimes, and again with unlooked-for subsequent failure. He will learn the practical side, construction of vats, pumping and filtering corrosive liquids, leaching solids, absorbing gases, furnace design, combustion of coal and gas, conduction of heat through a charge, the heating character of a flame, handling materials and handling men. In short, he will absorb the thousand and one things that make up the practical engineer.

He will learn at work, and when he is not apparently thinking. He will find that a knowledge of the theory of choice and chance do not always conduce to a great poker player. He will see the personal equation solved before his eyes. He will learn a little by the successes of others. He will learn a little more by their failures. He will learn still more by his own successes, but most of all by his failures. He will find out that there are few things in his college course, from the athletic field to the lecture room, that did not help him, and as the writer sees things and knows things, he should not blame the broad training he has received if he does not "win out" at the end.

Electrometallurgist.

During the eight months of the current year, ending with August, the gold production of Australia was 2,441,737 ounces. The corresponding figure for 1903 was 2,489,820 ounces.

SYNOPSIS OF ARTICLES IN OTHER JOURNALS

A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.

INDUSTRIAL ELECTROCHEMISTRY AND ELECTROMETALLURGY.

Electrometallurgy of Zinc.—In our September issue we gave some notes on recent developments in the electrometallurgy of zinc. In the *Zeit. f. Elektrochemie*, September 2 and 23, J. HESS gives a review of processes patented or described during recent years. He first deals with the electrolysis of aqueous zinc solutions and notices briefly the processes of Amberg, Strzoda, Sadtler, Ellershausen and Western, Tossizza and deals at greater length with Hoepfner's process (ELECTROCHEMICAL INDUSTRY, Vol. I., pages 357, 540, 568). The author then deals with electrolysis of fused zinc salts and describes the process of Swinburne and Ashcroft (ELECTROCHEMICAL INDUSTRY, Vol. I., page 412; Vol. II., page 404). He then gives an interesting discussion of electric furnace processes for zinc production. The low utilization of the heat in the ordinary metallurgical zinc process is the reason why better results may perhaps be expected from the electric furnace, on account of the greater local concentration of heat in it. According to statistics of the mines of upper Silesia in 1901, there were required for 100 kg. of zinc 230 to 330 kg. of reducing material, 800 to 1100 kg. of carbon for heating, 50 to 80 kg. of clay, and $1.07 to $2.00 wages. Fifty to 70 per cent of the ores was calamine, the balance roasted blende. The total loss of zinc is 20 to 25 per cent. In Rheinland 300 to 400 kg. of carbon for heating are used per 100 kg. of zinc and the loss of zinc is 10 to 12 per cent with skilled workingmen. The zinc ores used contain 40 to 60 per cent of zinc. One kw.-hour is equivalent to 870 kg. calories, or about ⅛ kg. of coal of 7000 kg.-calories; with a price of coal of 0.3 cent per kg., and a price of 0.3 cent per kw.-hour, one kw.-hour is equivalent to one kg. of coal. "If, therefore, the 3 to 10 kg. of coal required at present per kg. of zinc are to be replaced by electric heating, this can be done if 3 to 10 kw.-hours (according to the content of zinc in the ore) are sufficient for the production of one kg. of zinc. It is stated that in practice only about 5 kw.-hours are required for 40 per cent ore, which would be equivalent to a seven times better utilization of heat, compared with the ordinary metallurgical process." He concludes that the electric furnace is perfectly suitable for zinc production if a larger water power is available near the zinc works. The electric furnace process is thought to be especially suitable if the zinc ores contain lead. Siemens & Halske patented the electric furnace shown in Fig. 1 (English patent 11,438, 1898). Upon the carbon tube K the condensation chamber H is set, which is surrounded by the charge, so that by heat conduction the temperature in it is maintained at 500 to 900° C., as required for condensing the vapors. The maximum temperature is at B. The slag is removed through O. The vapors escape through the carbon tube, and were expected to condense in the condensation chambers to liquid metal, but only zinc powder was obtained. C. Casoretti and F. Bertani (German patent 129,889, December 13, 1899) treat roasted zinc ores in such a way that the ore mixed with reducing agents is first heated in muffles up to the temperature of distillation of Zn, and the further increase of heat is obtained electrically. Their apparatus is shown in Figs. 2 and 3. The ore mixed with the reducing material is introduced into muffle *a* and drops into the muffle *b*, stirring being provided by *e*. The muffles *a* and *b* are heated from *c*. In *b* the ore is reduced. It is then brought between the electrodes *f*, where it is melted with resulting total distillation. The zinc vapor passes through the canals *k* into the condensation room *i* and the slag is removed through *n*. It is stated that a furnace of this kind has been installed by the Societa Elettrometallurgica Lombarda, requiring per kg. of Zn two hp.-hours and 15 per cent of carbon for reduction. Experiments made to reduce zinc from unroasted blende by adding lime and carbon in ordinary furnaces have been unsuccessful. Darmstaedter (German patent 132,205, September 19, 1899) heats zinc blende in the electric furnace with additions of iron or iron oxide and carbon, whereby, instead of iron oxide, other materials like lime may be used. Zinc is distilled while calcium sulphide is obtained as fused slag. If blende is heated without addition of carbon, but with the other above additions, zinc oxide is obtained which is then treated afterwards, after removing the slag. The author describes the processes of Dorsemagen and Borchers (ELECTROCHEMICAL INDUSTRY, Vol. I., pages 105 and 189) and briefly mentions the processes of A. K. Picard (*Chemiker Zeit.* 46, June 10, 1903; 27, April 2, 1904), P. Danckwardt

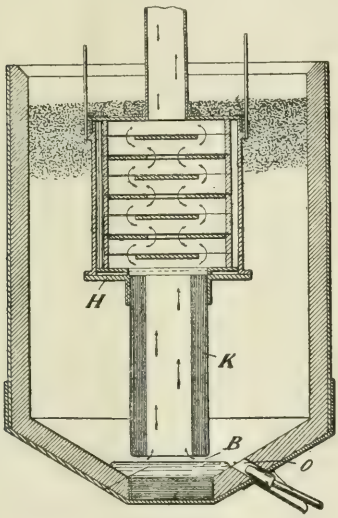


FIG. 1.—SIEMENS & HALSKE ZINC FURNACE.

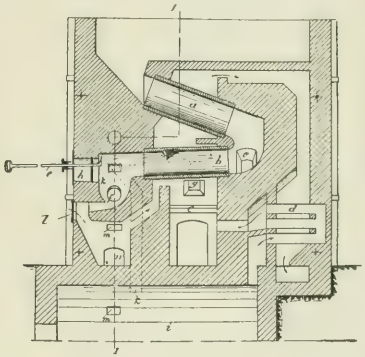


FIG. 2.—CASORETTI AND BERTANI ZINC FURNACE.

(U. S. patent 746,798, October 15, 1903), O. W. Brown and W. F. Oersterle (U. S. Patent 742,830, May 14, 1903) and then describes the process of De Laval (ELECTROCHEMICAL INDUSTRY, Vol. II., October, 1904, page 423). It is stated that by this process zinc is produced with 2400 hp. in Hafslund, Norway. However, no ore is reduced, but only spelter is treated electrically and refined zinc of 99.9 per cent purity is obtained. A. Salgues used in Crampagna a tightly-closed electric furnace for production of zinc from ores (French patent 330,665, March 28, 1903); he gets, however, only zinc powder. The reason is that the zinc vapors are diluted by CO. In order to get solid zinc it is necessary to reduce the ores preliminarily at a lower temperature in an auxiliary furnace, so that no great quantities of CO are obtained in the distillation furnace.

Aluminium.—A pamphlet, issued by the U. S. Geological Survey, deals with the production of aluminium and bauxite

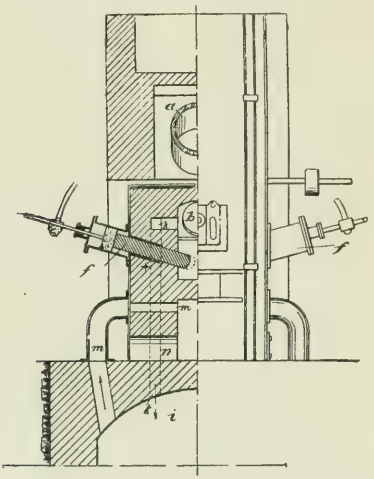


FIG. 3.—CASORETTI AND BERTANI ZINC FURNACE.

in 1903, the author being J. STRUTHERS. The production of aluminium in the United States during 1903 is estimated at 7,500,000 pounds (against 7,300,000 in 1902, 4,000,000 in 1897, 1,300,000 in 1896, 61,281 in 1890, and 83 in 1883). A review is given of the outcome of the patent litigation between the Pittsburgh Reduction Co. and the Electric Smelting & Aluminum Co. (see our Vol. I., pages 519, 522, 560). The prices of aluminium in the United States from 1901 to 1903 are given as follows:

	Small Lots	100 Lb. Lots.	1000 Lb. Lots.	5000 Lb. Lots.
	c.	c.	c.	c.
No. 1 aluminium (99.75 per cent)	37	35	34	33
No. 2 aluminium (90 per cent)	34	33	32	31
Nickel-aluminium casting metal (10 p. c. ni.)	39	35	34	33
Special casting alloy (80 per cent al.)	35	30	29	27

The price of ingot aluminium during 1903 was adjusted by an agreement between all of the aluminium producers of the world. Then follow data on aluminium imports into the United States from 1870 to 1903. In 1903 the imports amounted to 498,655 pounds ($139,298) of crude aluminium and 4276 pounds ($2,818) of plates, sheets, bars and rods. The import duty is 8 cents per pound for ingot metal, and 13 cents per sheet for manufactured metal. The information contained in the pamphlet on the process of making aluminium, as practiced in the United States, contains nothing new to our readers. Concerning the industries in foreign countries the following notes are interesting. The works of the Société Electro-Métallurgique Française, at La Praz, Savoy, France, use 9000 amperes at from 110 to 130 volts. Two of the dynamos are of the unipolar type. Aluminium is used for conductors. The output is mainly aluminium, although ferro-alloys are also made. The works of the Compagnie des Products Chimiques d'Alais, at Calypso, near St. Michel, Savoy, France, use 4000 amperes. "The bath of fused material is covered with a layer of charcoal, which diminishes the loss of heat by radiation. The proper alumina content of the bath is maintained by spreading a fresh layer of the material on the top of the charcoal, and from time to time pushing small quantities of it into the molten bath. The condition of the electrolyte in each furnace is continuously indicated by the brightness of a 10-volt incandescent lamp. The molten aluminium, containing from 99.5 to 99.6 per cent of metal, is removed from the bottom of the bath every hour by tilting the furnace, which is supported on trunnions for this purpose." The Aluminium-Industrie-Aktien Gesellschaft has now a total of 24,000 hp. available at its three plants at Neuhausen, Gastein, and Rheinfelden; "the chief product is aluminium, but high-grade carbide is also made, and experimental work is now being carried on in other electrolytic and electric furnace processes." The works of the British Aluminium Co. have also been enlarged.

Concerning the uses of aluminium, it is said that its employment for electrical conductors instead of copper is still expanding and is one of the most important outlets for the domestic production. "A company has been formed to manufacture on a commercial scale the new explosive, ammonal, which is composed of powdered aluminium and ammonium nitrate, in respective proportions, depending upon the explosive strength desired. Ammonal is reported to be extremely safe to handle, impervious to water, and of great explosive strength." Concerning aluminium alloys, reference is made to the paper of J. W. Richards, abstracted in our Vol. I., page 498. As one of the most promising fields for the consumption of aluminium, the Goldschmidt thermit process is mentioned. A large proportion of the output of aluminium is manufactured into articles for domestic and culinary use; for construction of machine parts which require lightness rather than great strength; as a substitute for stone and zinc lithographic work; in the rubber industry for making lasts and boot trees upon which rubber shoes and boots are made; in cast-iron foundry practice as a substitute for wood in making bobbins for spinning and weaving machines treating silk fiber, and in powdered form for the manufacture of white metallic paints, a use to which it is particularly suited, on account of its non-susceptibility to atmospheric influences. Among the proposed new uses of aluminium is its substitution for the glass carboys or earthenware vessels employed for the transportation of nitric acid, and also as a substitute for zinc in lining cisterns and other receptacles for storing water.

Bauxite.—The same Geological Survey pamphlet of J. STRUTHERS contains the following information on bauxite. There was a large increase in the production of bauxite in the United States during the year 1903, due mainly to the development of the industry in Arkansas, the total quantity shipped amounting to 48,087 long tons, valued at $171,306, as compared with 29,222 long tons, valued at $128,206, in 1902. These figures show an increase in quantity of 18,865 tons, or about 65 per cent, and in value of $43,100, or 34 per cent. At the present time, Georgia, Alabama and Arkansas, in the order of their outputs, furnish the total supply of bauxite in the United States. The world's production of bauxite in 1902 was 135,877 metric tons. The chief factor of interest during 1903 was the completion and the putting into operation of the mining plant of the Pittsburg Reduction Co., at Bauxite, Ark. The plant has been carefully designed with the view of replacing hand labor by machinery, wherever possible. Mechanical

conveyors and elevators transport the crude ore from the cars through the mill and finally store the finished product in bins ready for shipment. A second point of interest to the industry is the new refining plant of the Pittsburg Reduction Co., at East St. Louis, which was put in operation during the latter part of the summer. The plant is similar in detail to the refining plant of the company at New Kensington, Pa. The crude ore, which was formerly shipped from Arkansas to New Kensington, is now refined at East St. Louis by the soda process, which removes the impurities, iron and silica. The equipment includes a bank of coke ovens for cooking Illinois coal, which, so far, have given very satisfactory results. If the bauxite is to be used for the manufacture of alum, it is merely crushed, dried and shipped in bulk in box-cars, but if for the manufacture of aluminium metal or artificial corundum, which requires a low silicon content, the crushed ore is first passed through a log washer in order to remove the sterile siliceous gangue. The principal salts of aluminium are aluminium sulphate and crystallized alum, for the manufacture of which bauxite and Greenland cryolite are consumed. In 1903 the production of aluminium sulphate was 80,726 short tons, valued at $1,614,520, as compared with 80,075 short tons, valued at $1,938,671, in 1902, and that of crystallized alum was 7574 short tons, valued at $210,910, as compared with 8539 short tons, valued at $299,500, in 1902.

Electrolytic Iron.—In view of the recent paper of Burgess and Hambuechen (Electrochemical Industry, Vol. II., page 283) an article by A. Skrabal, published in *Zeit. f. Elektrochemie,* September 23, is interesting. He distinguishes two essential different methods yielding two different kinds of electrolytic iron. In the first method a ferrous salt is used as electrolyte, and iron as anode, with a low voltage and a low current density. He calls iron produced by this method A-iron. The second method is characterized by the use of platinum as anode, high voltage, high current density, and an electrolyte containing bivalent iron in some complex form. Iron made by this method is called by him B-iron. The A-iron is of silver-white color, compact and extremely hard. The B-iron is of more grayish color, less compact and less hard. Since the conditions of these two methods may be combined at will—for instance, ferrous chloride as electrolyte, iron as anode, high-current density and voltage, or complex ferrous salt as electrolyte, iron as anode and low current density—it is possible to get a great many different kinds of electrolytic iron which in their properties are more or less similar to A- or B-iron. The author gives some historical data on experiments made by various investigators. All make A-iron by using an electrolyte of ferrous chloride, ferrous sulphate or ferrous ammonium sulphate, perhaps with an addition of $MgSO_4$, $MgCl_2$, $(NH_4)_2SO_4$ or NH_4Cl to increase the conductivity, while iron is used as anode. The differences in the various processes consist in the current density and temperature, while in some cases stirring is used, but not in all cases. The author describes first his method for producing a pure ferrous ammonium sulphate (Mohr's double salt). As anode he then uses a platinum electrode of 5 x 2.5 cm. size, covered with electrolytic iron by Classen's method. As cathodes he uses two platinum sheets of the dimensions 2.5 x 1 cm., which, before they are suspended in the bath, are heated to white heat and afterwards moistened with alcohol. The electrodes are suspended in the electrolyte in such a way that the distance of the upper rim from the surface of the latter is 0.5 cm.; the distance of the two cathode sheets from the anode is 1 cm. The covered beaker which contains the electrolyte must be quite high, so that the anode slime falls to the bottom without spoiling the solution. After electrolysis is completed, the cathodes are washed with water, alcohol and ether. If the anode is replaced from time to time by a new one, it is possible to obtain the A-iron in form of plates of any thickness. This iron is of a beautiful silver-white color, very bright and probably of crystalline structure. If a platinum electrode covered with such A-iron is placed in warm dilute sulphuric acid, the iron dissolves only very slowly, gas bubbles being developed on the platinum wire. Neuburger (Electrochemical Industry, Vol. II., page 319) produced electrolytic iron which did not rust. The present author did not observe this property with his iron. When exposed to moist air, it rusts, although not as easily as commercial iron. On the other hand, he obtained in some cases an iron which had an extremely high resistivity against chemical influences. The very great hardness of all A-iron is generally supposed to be due to the content of hydrogen. But the author does not think that the different content of hydrogen represents the whole difference between ordinary electrolytic iron and electrolytic iron, which has been subjected to high heat. It seems that these two represent two different allotropic conditions of iron.

Nickel Plating.—An article by A. A. Beadle, in *The Metal Worker, Plumber and Steam Fitter,* and reprinted in the *Metal Industry* of September, deals with the management of nickel plating baths. Nickel platers are generally careful to procure only pure and neutral ammonium sulphate for their plating solutions, and to keep their bath permanently neutral. A comparatively soft nickel anode is better than a hard, rolled one. When an ordinary nickel plating bath, containing about ¾ pound of nickel ammonium sulphate to the gallon of water is started, the current efficiency of the cathodic deposition is between 90 and 100 per cent. To maintain it at this value, it is necessary to maintain the nickel content in the bath constant; in other words, to see that the anode properly dissolves. The author then gives a review of the results obtained by O. W. Brown on this point (see Electrochemical Industry, Vol. I., page 487).

Sterilizing Milk by Electricity.—In the *Zeit. f. Elektrochemie,* of September 2, G. Guarini gives a brief outline of experiments made on the sterilization of milk. If the milk is heated, its chemical composition is changed, and this should be avoided under all circumstances. The author, together with Samarani, used alternating current of 110 volts and carbon electrodes. At another place he speaks of platinized carbon electrodes. The current and frequency are not given, but it is stated that if the current is strong enough the milk will be completely sterilized without any coagulation. Two points are of special importance, the length of treatment and the current.

Electrometallurgy of Iron and Steel.—An illustrated review of the various types of electric furnace, proposed for this purpose, is given by A. F. Schneider in the August issue of the *Mining Magazine.* The article contains nothing new to our readers, except the diagrams on page 115, which, however, lack explanation.

Theoretical and Experimental.

Electrolysis of Potassium Acetate.—A paper by F. Foerster and A. Piguet, published in *Zeit. f. Elektrochemie,* September 16, deals with the anodic reaction during electrolysis of potassum acetate with anodes of different materials. The authors showed that three main phenomena are to be distinguished: First, development of oxygen; second, oxidation of acetic acid to carbonic acid; third, formation of ethane. According to the nature of the anode material one or the other of these different reactions prevails. The main point of interest is that the action of the anode metals is the same as should be expected from their anode potentials in electrolytes when developing oxygen.

Anodic Development of Oxygen.—In connection with the article of F. Foerster on electrolysis at smooth and platinized platinum anodes published in our Vol. I., page 443, the results given in *Zeit. f. Elektrochemie,* September 9, by F. Foerster and A. Piguet should be interesting. Former authors have already pointed out that a different anodic poten-

tial is required at anodes of different materials in order to start the development of oxygen. The present authors have investigated how the anodic voltage required for continual development of oxygen during continuous electrolysis at different anodes changes with the time. Part of the results are given in Fig. 4, which refers to electrolysis of 2nKOH with one ampere, with a current density of 0.033 ampere per square centimeter at 15° C. It will be seen that at polished platinum the anodic voltage increases rapidly, and, after one ampere-hour, reaches a constant value. Iridium shows the peculiar feature that the voltage having reached a maximum is then decreasing again; this is due to the fact that iridium

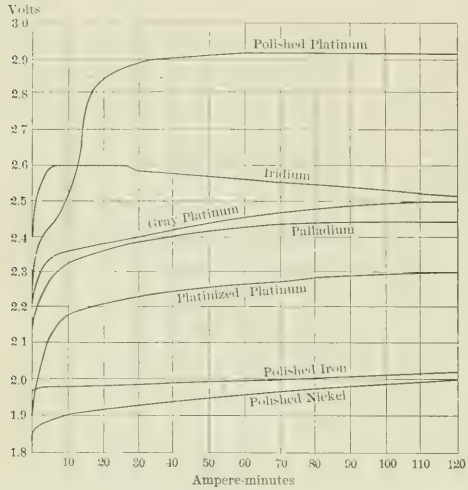


FIG. 4.—POTENTIAL REQUIRED FOR OXYGEN DEVELOPMENT.

dissolves in small quantities. The author gives his reasons why he believes F. Haber's explanation to be correct that polished electrodes at which gas is developed are surrounded during electrolysis with a thin atmosphere of gas, which is kept attached to them by adsorption.

Electrolysis of Bromides of Alkalies.—While the phenomena during the electrolysis of chlorides and iodides have been carefully analyzed during recent years, the analogous phenomena during bromide electrolysis have been less studied. H. Kretzschmar, in a long paper published in *Zeit. f. Elektrochemie*, October 7, gives an account of an experimental investigation which enables us now to compare completely the electrolysis of chlorides, iodides and bromides. The author first studied the purely chemical side of the question, *i. e.*, the action of bromine upon alkalies. When bromine acts upon an alkali hydroxide solution, always hypobromite is first formed. The process proceeds in such a way that the following two equilibria result,

$$Br_2 + OH' \rightleftarrows HOBr + Br'$$
$$HOBr + OH' \rightleftarrows BrO' + H_2O$$

When one molecule of bromine acts upon an equivalent of alkali, considerable quantities of both remain first unchanged. Hypobromous acid and bromide act upon each other even at very low concentration and yield free bromine and alkali, or hypobromite. Whenever hypobromous acid, or bromine, come into contact with hypobromite, bromate is formed according to the equation,

$$2HOBr + MOBr = MO_3Br + 2HBr.$$

This process is quite analogous to the formation of chlorate from hypochlorous acid, or free chlorine, but there are the following differences. The formation of bromate has a velocity constant 100 times that of chlorate formation; and, on account of considerable hydrolysis of hypobromite, the bromate formation starts even in a slightly alkaline solution with considerable speed. In a somewhat more alkaline solution (0.1 normal or more) hypobromite and hypochlorite are stable to about the same degree. With increasing alkilinity the speed of the hypobromite solution increases again slowly. A second process sets in, which leads from hypobromite to bromate, but has a very much lower speed than the first one.

Concerning the electrolysis of bromide solutions, Kretzschmar has established the following facts. When neutral bromide solutions are electrolyzed, free bromine is developed at the anode. The bromine, reacting with the free alkali coming from the cathode, yields hypobromite. The concentration of hypobromite reaches a constant value, when the electrolysis is continued for some time; only bromate is then formed in the solution, which before that moment increased more slowly than the hypobromite. At a polished platinum anode oxygen is developed in increasing quantity with increasing content of hypobromite in the solution; the proportion of the current which produces oxygen, becomes constant with the hypobromite concentration and is never more than 9 per cent of the total current. At a platinized anode the anodic development of oxygen is very small, with moderate stirring and the current which produces oxygen is less than 1 per cent of the total current. In other words, the efficiency of the formation of the bromine-oxygen compounds is almost theoretical. At the same time, the anode potential is only about 0.3 volt less negative than at a polished anode under otherwise the same conditions. The hypobromite concentration which can be obtained is the higher, the higher the bromide concentration and the current density and the lower the temperature; it is higher at a platinized anode than at a polished anode. During electrolysis of strongly alkaline bromide solutions, hypobromite is again first formed up to a concentration, but at the same time bromate is formed from the beginning in considerable quantities. Even in normal alkaline bromide solution free bromine may be obtained at the anode in visible quantities; and this takes place more easily at a platinized than at a polished anode, and in greater quantities with increasing bromide concentration and current density. If free bromine is not developed in considerable quantities at the anode, only a small hypobromite concentration is obtained, and the anodic development of oxygen decreases with progressing formation of hypobromite, the proportion of the current consumed for the generation of oxygen being about 10 per cent of the total current. The author develops his theoretical views on the primary or secondary nature of the various ionic reactions. He finally gives the following table:

There is Formed	In Acid Solution	In Neutral Solution	In Strong Alkaline Solution
Chlorate..	Secondarily	By anodic discharge of Cl O'	
Bromate..	Secondarily		By anodic oxidation of Br O'
Iodate....	Secondarily		

Electrolysis of Copper Sulphate.—In the *Zeit f. Elektrochemie*, September 16, F. Foerster and G. Coffetti discuss the various ionic reactions at the anode and cathode during copper sulphate electrolysis. They refer to the fact that if a platinum cathode is suspended in a normal copper sulphate solution, current passes, even when its potential is still about 0.1 volt more negative than the proper potential of copper against the solution. In this case no copper is deposited upon the cathode, but the reaction consists in the cathodic re-

duction of bivalent copper to monovalent copper. While the article is mainly theoretical, the views expressed by the authors throw some light on various facts known to copper refiners. At the copper anode the following three processes may occur:

$$(1)\quad Cu + F \rightarrow Cu^{\cdot}$$
$$(2)\quad Cu + 2F \rightarrow Cu^{\cdot\cdot}$$
$$(3)\quad Cu^{\cdot} + F \rightarrow Cu^{\cdot\cdot}$$

where F means a positive charge of 96,540 coulombs (one positive electron). These three processes will go on in such a way that an equilibrium between $Cu^{\cdot\cdot}$ and $Cu^{\cdot}$, near the anode, is established according to $Cu^{\cdot\cdot} + Cu \rightleftarrows 2Cu^{\cdot}$. As long as the solution is far from this equilibrium that one of the three reactions (1), (2), (3), will take place which is able to establish the equilibrium. Thus, if a copper anode is suspended in a copper-sulphate solution reaction (1) will take place and will produce the necessary quantity of cuprous sulphate. But if this quantity should for some reason become greater than required for the equilibrium, the reaction (3) will regulate the matter. When the equilibrium at the anode is then reached, (1), (2), (3) go on simultaneously in such a way that the equilibrium is maintained; that means, reaction (2) prevails, and with respect to the dissolved quantity of copper the total effect is the same as though reaction (2) was the only one, as long as there is no influence exerted on the $Cu^{\cdot}$ ions in the solution; but this is always the case. As well known, during electrolysis with pure copper anodes, their decrease in weight is not inconsiderably greater than the quantity of copper simultaneously deposited on the cathode. This great decrease of anode weight is sometimes assumed to be due to the action of atmospheric oxygen upon the anode copper, although this would not explain why the anodes dissolve uniformly over the whole surface, and are not attacked most strongly at the contact points of the solution and the air. As a matter of fact the action of atmospheric oxygen upon the quantity of copper dissolved from the anode is only indirect, in so far as cuprous sulphate produced by the current is oxidized to cupric sulphate by means of the reaction $Cu_2SO_4 + H_2SO_4 + O \rightarrow 2CuSO_4 + H_2O$; in this way the concentration of cupric sulphate increases and sulphuric acid is consumed. This is the process which in copper refining has an unfavorable effect on the conductivity of the electrolyte, so that the latter must be regenerated from time to time in tanks with insoluble anodes. Increasing temperature favors the cuprous sulphate formation at the anode and at the cathode. Schwab and Baum's experiments (Electrochemical Industry, Vol. I., pages 484 and 584) confirm this and show the fact that the relation of anode loss to cathodic deposit approximates the value unity with increasing current density.

Deposition of Zinc from Zinc Chloride Dissolved in Acetone. The October issue of the *Journal of Physical Chemistry* contains a full account by H. E. Patten of his experimental investigation, a preliminary account of which was published in our August issue, 1903. From his later experiments he concludes that the deposition of zinc from acetone solution is not well adapted to produce chemically pure zinc or to give a thick coat for chemical purposes. This does not diminish, of course, the scientific interest of the work.

Electrolytic Solution of Platinum in Hydrochloric Acid.—Platinum is generally used for electrodes, in spite of its high price, on account of its resistivity against chemical reagents. In ordinary work platinum is considered practically indestructible. Nevertheless, it has long been known that under certain conditions platinum may dissolve, and it is of importance to know these conditions in order to guard against them. In *L'Electricien*, of September 10, D. Tommasi gives some notes on the electrolytic solution of platinum anodes in hydrochloric acid solutions. He experimented with a U-tube in the two arms of which two electrodes of chemically pure platinum were suspended, the current being furnished by two Daniell cells in series. With fairly concentrated hydrochloric acid, density 1.180, he first did not get any development of gas at the anode; at the end of an hour a few gas bubbles appeared at the anode, while after twenty hours the production of compounds, containing oxygen and chlorine, still continued at the anode. Upon analysis of the liquid a residue of perfectly pure platinum was obtained, but the quantity is not stated. With smaller concentrations of hydrochloric acid, less and less platinum dissolves, until in a solution containing 5 c. c. of acid of density 1.180 and 100 c. c. of distilled water, no trace of platinum could be found in the liquid, after the current had passed for 100 hours.

Ionic Mobilities and Conductivity.—F. Kohlrausch's classical researches on the conductivity of dilute aqueous solutions are well known. For very dilute solutions his conductivity measurements, taken together with the determination of transport numbers by Hittorf and expressed in the terminology of the model of traveling ions, led him to the fundamental result that the conductivity is directly proportional to the sum of the ionic mobilities of the ions participating in the transportation of the current, whereby each ion has a distinct mobility depending only on its chemical nature and independent of the other ions present in the solution. He showed that when the mobilities are known, the conductivities may be calculated with a high degree of accuracy. These researches were to the greatest part confined to monovalent ions. F. Kohlrausch and E. Grueneisen have now examined the conductivities of aqueous solutions of electrolytes with a number of bivalent ions, such as Ba, Sr, Ca, Mg, Zn, Cd, Cu, Pb in the form of sulphates, nitrates and chlorides. The results are published in the *Sitzungsberichte der Preussischen Akademie der Wissenschaften*, July 28, and an abstract is given in the London *Electrician*, September 30. The authors find considerable difficulty in deriving the conductivity from the ionic mobilities. To obtain the conductivity at infinite dilution by extrapolation is more difficult than it is in the case of monovalent ions, since the rise is from two to five times as great. The difficulty, which can be more or less surmounted when at least one of the ions is monovalent, becomes insuperable when both are bivalent. The supposition that an ion has always the same mobility at a very high dilution is conditioned by the water taking no part in the conduction. This is no doubt true at infinite dilution, but there is no knowing up to what dilution the influence of the water continues to be felt. Hydrolysis is more likely in the case of bivalent ions than in the case of monovalent ions. A fraction of 1 per cent in the way of hydrolysis would account for the discrepancies found in magnesium sulphide. It is remarkable that all recent experimental investigations in the theory of solutions point to the importance of taking the influence of the solvent into account.

Transport Number of Sulphuric Acid.—O. F. Tower has made a very careful redetermination of the transport number of sulphuric acid. The results are published in the September issue of the *Journ. Am. Chem. Society*. From experiments made between 8 and 32° C., and with concentrations between normal and 1/50 normal, he finds that in dilute solutions the transport number may be represented by $0.1788 + 0.0011\,(t - 20)$, when t is the temperature in degrees Celsius. There appear to be no HSO_4' ions beyond the concentration 1/10 normal. The most probable value of the migration number (mobility) of the SO_4'' ion is 70, in accordance with F. Kohlrausch.

Miscellaneous.

Anaconda.—To the *Engin. and Mining Jour.* of September 22, Charles S. Palmer contributes an article entitled "the casual observer at Anaconda." A very concise outline is given of the plant and the process. He sums up his main impressions as follows. "The great phenomena, aside from the general magnitude of this 5000-ton plant, should include the

use of compressed air, both in furnace and surface traction, the fairly successful attemtp to save and re-treat flue-dust, the saving of steam fuel by the harnessing of the reverberatories to the Sterling boilers, and the high degree of purity of the anode copper. Any one coming away from the new works cannot overlook the long string of ruins representing the old works, from the refuse of which thousands of tons of material of every description are being treated every month." The anode copper was formerly refined at the large electrolytic refinery at Anaconda; but the metal is now shipped East for further treatment. The anode copper as finished at the Washoe works, runs about 99.6 in copper, and with some gold and considerable silver, so that all the work done at Aanaconda is now simply one of concentration of values.

Wet Process for Copper Extraction.—The mines department of Queensland had requested L. C. Ball to collect information concerning wet copper processes, especially those applicable to Queensland ores. His report is published in the *Queensland Gov. Mining Jour.* of May and June, and is a concise summary of the various processes. A long abstract of it is given in the *Mining Magazine* of September.

Metallurgy of Copper, Lead and Zinc.—A very interesting general outline of the development of the metallurgical methods now in use in this country for the treatment of copper, lead and zinc ores, is given by W. R. Ingalls in the July issue of the *Mining Magazine.* The author emphasizes it is the best metallurgical practice which extracts the most money from a given kind of ore. This principle should always be kept in mind. "Attention is frequently called to the waste of sulphur in burning sulphide ores. It would, indeed, be a waste if there were a market for sulphuric acid where such ores are smelted, but if there be no market it may not be a waste at all." The author deals at some length with roasting furnaces and processes, and briefly discusses the problem of pyritic smelting.

Cadmium in Spelter.—Some editorial remarks are made in the September issue of the *Metal Industry* with respect to the effect of cadmium, contained in certain varieties of spelter, upon brass. The writer does not share the opinion, sometimes expressed, that cadmium is harmful. He conducted a series of experiments on the influence of cadmium on the rolling properties of brass, and amounts of pure cadmium were added to brass in quantities up to 0.50 per cent without showing that it had any deleterious effect beyond a slight hardening. As far as the influence of cadmium on the casting qualities of brass is concerned, the opinion is expressed that it may have rather a good effect. Cadmium has a strong affinity for oxygen and so acts as a deoxidizer. In fact, it has become standard practice to add cadimum to sterling silver for this purpose.

Analysis of Molybdenum in Steel.—In the June issue of the *Jour. of the Amer. Chem. Socy.* F. Van Dyke Cruser and E. H. Miller discuss the best method for accurately and rapidly estimating molybdenum in steel and steel-making alloys. The main result is that molybdenum can be completely separated from an acid solution containing iron, using hydrogen sulphide under pressure, the precipitate being slightly contaminated by iron, which is probably held mechanically and cannot be washed out; it is necessary to remove this iron subsequently by ammonium hydroxide. This method of separation of molybdenum from iron is more accurate than the use of either sodium or ammonium hydroxide.

Determination of Sulphur in Iron.—In a critical discussion of the usual methods for this purpose, published in the July issue of the *Jour. Amer. Chem. Socy.*, A. P. Ford and O. G. Willey strongly recommended Bamber's method. They use it as follows. A 2-gram sample of drillings is dissolved slowly in nitric acid in a platinum dish, using an inverted watch-glass over the drillings. After the iron is completely dissolved the watch-glass is removed from the solution, 1 gram of potassium nitrate added and the solution evaporated to dryness and ignited over a Bunsen burner at a good red heat for three or four minutes, turning the dish so that the side, as well as the bottom is heated to redness. Add 50 c. c. of 1 per cent solution of sodium carbonate, boil for a minute or so, filter, using paper pulp, and wash with hot 1 per cent sodium carbonate. Acidify filtrate with hydrochloric acid and evaporate to dryness. Take up in 50 c. c. water and 2 c. c. strong hydrochloric acid, filter, wash, and in the filtrate, which should be about 75 or 100 c. c. in bulk, precipitate the barium sulphate with barium chloride.

Pig Iron from Briquettes.—One of the difficulties arising in connection with magnetic separation of iron ores is due to the difficulty of treating the fine concentrates in the blast furnace. Various means have been tried to overcome this difficulty. In a very original way, for instance, M. Ruthenburg applies the electric furnace to agglomerate the fine particles and bring them to a temperature at which they may be reduced afterwards in a soaking pit. On the other hand, many attempts have been made to briquette the concentrates, and a very interesting article concerning a process of this kind worked at Herraeng, Sweden, is described by Henry Louis in the *Jour. of the Iron and Steel Institute* of May. The magnetite received from the magnetic concentrators is mixed with a binding material and stamped into briquettes which are burned in the briquetting furnace. The temperature in the latter reaches 1300° C., and at this heat the magnetite agglutinates sufficiently to form a firm, hard briquette. At the same time the briquette furnace acts as an exceptionally efficient calciner for removing practically the whole of the sulphur; the concentrates retain a notable proportion of sulphur, but this is almost entirely eliminated in the briquetting process, as shown by the following analysis of a briquette:

	Per cent.
Silica	7.50
Peroxide of iron	86.99
Protoxide of iron	0.55
Alumina	0.80
Oxide of manganese	0.70
Lime	3.40
Magnesia	0.20
Phosphorus	0.002
Sulphur	0.016
	100.158
Metallic iron	61.32

The briquettes are then hoisted to the top of a pair of charcoal blast furnaces, where they are smelted for high-class pig iron; the waste gases from the blast furnace fire the briquetting furnaces, supply gas for the engines which furnish the blast, and also drive the dynamos of an electric central station, from which power is conveyed to the concentrating works, as well as to the various mines for hoisting, pumping, etc.

Fuel Briquetting.—The October issue of *Mines and Minerals* contains the first of a series of articles by J. Fulton on the fuel briquetting industry. The author deals with the materials of which bricks are made, the binders, the fuel value, the shapes of briquettes and describes the processes and machinery used.

Bricking.—A bricking plant for flue dust and fine ores is described and illustrated by J. C. Bennett in the *Engr. and Min. Jour.*, September 15.

Quicksilver.—A long article by W. Forstner on the quicksilver deposit of California is published in the *Engr. and Min. Jour.*, September 8 and 15.

Gold.—The October issue of *Mines and Minerals* contains the first part of an illustrated article by F. A. Thomson and S. L. Goodale on the 300-ton chlorination plant of the Portland Gold Mining Co. at Colorado Springs, Col. In the pres-

ent installment the crushing, sampling, bedding and roasting of the ore is described.

Manufacture or Repair of Articles Made of Quartz.—A note in the London *Electrical Review* of September 30, gives the following abstract of a German patent granted to P. ASKENASY. "A quantity of quartz sand is laid upon a suitable support of the same material, and fused into the desired shape by means of an electric arc, which is moved over the surface of the mass as it melts. When such an object as a basin is being made, the quartz is first mixed with some agglutinant, such as 1 per cent of starch solution, petroleum residue, lavender oil, or the like. The arc is struck between sloping electrodes of small diameter, high voltages being employed; and in order to hinder their rapid consumption, the operation is conducted in an indifferent atmosphere, such as one of carbon monoxide. In certain cases it may be desirable to add to the quartz some metallic oxides, like alumina, stannic acid, titanic acid, etc., as these reduce the melting point; but the quantity introduced must be too small seriously to affect the coefficient of expansion. During the fusion a dust of quartz may be allowed to fall round the arc, for in this manner any holes produced are instantly sealed up. The same process is available for the repair of any cracks or flaws in articles already constructed of quartz."

Evolution of Metallic Structure.—In a paper published in *Comptes Rendus*, August 16, and abstracted in the London *Electrician*, of September 9, G. CARTAUD reports having found traces of a cellular structure in the soft metals, lead, tin and zinc, which he has succeeded in polishing and etching. Lead, which is the most difficult to polish, also presents the most decisive evidence of cellular structure. When attacked by picric acid dissolved in acetone it shows a completely closed microscopic net work of cells. "There is, however, evidence to show that this network is shown up by a kind of development, and is but the relic of an actual structure in what might be called the embryonic stage. Apart from this small cellular network, there is a much larger crystalline network which indicates the final stage of the solidification." The lines of this network are straight, and freely intersect the waving lines of the celluloid network. The author compares them to lines drawn along the course of a river, but so as to indicate the general or embryonic lines, but rectifies them. When an ingot is deformed and then annealed the relation between the crystalline and the cellular network disappears.

Mining in the United States.—The *Mining Magazine* of July contains an article, with map, by F. L. Ransome, on the geographic distribution of metalliferous ores within the United States, and an article by H. S. Fleming on commercial divisions of the competitive coal makers; in the August issue J. F. Kemp writes on the formation of veins, G. H. Ashley on the Cumberland Gap coal field; in the October issue E. C. Eckel gives a statistical review of the non-metallic mineral products of the United States, U. S. Grant on the Lake Superior iron ore deposits, W. H. Weed on occurrence and distribution of copper in the United States, D. H. Stovall on placer and hydraulic mining. In the July and August issues C. Henrich gives an interesting illustrated outline of silver mining in the Guanajuato district in Mexico.

Timbering in Mines.—A long illustrated article by J. H. BATCHELLER on timber and timbering may be found in the *Engin. and Min. Jour.*, September 15, 22, 29.

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

BY GEORGE P. SCHOLL, PH. D.

ELECTRIC FURNACE AND FURNACE PRODUCTS.

Compensating Terminal for Electric Furnaces.—H. N. Potter, New Rochelle, N. Y. Patent 770,312, September 20, 1904. Application filed August 6, 1903.

The object of the invention is to provide means for compensating the expansions of the various materials which constitute the terminals of an electric furnace, f. i., in cases where the furnace body consists of graphite, while the current terminals are of metal. Such compensation is for the purpose of preventing distortion of the terminals under the action of heat and consequent loss of energy by the increase of resistance. The drawing accompanying the specification shows such a terminal applied to a tube furnace. The tubular part of the latter fits into a terminal of the same material, also of tubular form, the second half of which is enlarged to about three times the diameter of the first half. Its outer end abuts against a terminal of copper, of still larger diameter. The graphite and the copper parts are joined by means of iron or steel bolts, which pass through the copper part, and without touching the graphite part, are connected to a flange resting upon the enlargement of the latter. It is stated that the essential thing in order to make the terminal "compensating" terminal, is that the bolts should have a co-efficient of expansion intermediate between that of the copper and the graphite terminal. Then by properly dimensioning the latter, the reactions of the parts under the influence of heat will just balance each other, so that the pressure between the two parts will practically remain constant under variations of temperature.

Incandescent Electric Material.—A. Voelker, Berlin, Germany. Patent 770,991, September 27, 1904. Application filed June 2,1904.

The process of manufacturing the above incandescent material consists in the granulation of carbon until the individual grains are substantially from one to seven millimeters in size. The material thus obtained is divided into groups, the first of which contains only grains of one millimeter thickness, the second grains of two millimeters, and so on. The conductivity of the various groups is graduated as desired either by the addition of graphite or of silicates, acording as to whether the conductivity is to be increased or decreased. What particular silicates are to be added, is not disclosed by the inventor, nothwithstanding that it would be a very important thing to know. The new material is stated to be spread in the same manner as fuel over the surface which is to be heated, or it is heaped up around the object to be heated, f. i., a crucible, muffle or furnace chamber.

Apparatus for Electric Heating.—W. S. Horry, Niagara Falls, assignor to Union Carbide Company, Patent 771,249, October 4, 1904. Application filed June 28, 1904.

The furnace is intended more specifically for the production of calcium carbide by the use of a polyphase alternating current, preferably one of many phases. The body to be heated is preferably circular, and one set of the terminals of the various phases of the current is connected to equidistant points around its circumference, while the other set of terminals is connected to a common or neutral point. The fur-

nace is illustrated in cross-section in Fig. 1. It consists of an annular stack provided with charging bell and hopper and outlet pipe 12 for the waste gases. One set of dynamo terminals is connected to the electrodes 1 to 8, the number of which is the same as the number of fixed successive windings in the fixed armature of the dynamo. The electrodes are cylindrical carbon rods, and eight of them are shown in each horizontal series, but in practice a much larger number is desirable. The electrode 9, which extends through the bottom of the furnace is connected to the neutral point of the dynamo. It may be provided with a central vertical tapping hole, 13, for withdrawal of the molten product. A large number of electrodes are preferably used, inasmuch as it is then possible to employ relatively small electrodes without unduly heating them or their terminal connections. For starting the furnace it is fed with an initial charge of lime and carbon, which may be one containing large pieces of carbon, which, by being in contact with each other at various points, afford directly a path for the current. In case the charge consists of a non-

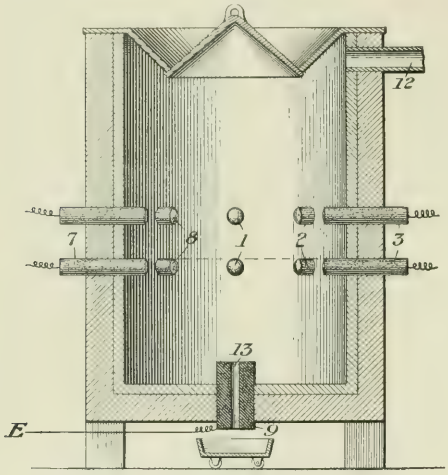


FIG. 1.—ELECTRIC FURNACE.

conducting mixture of coke and lime, an initial path for the current has to be provided by the use of a conducting charge or otherwise. In the normal working of the furnace the charge above the electrodes is heated sufficiently by conduction and radiation and by the waste gases arising from the zone of reduction. The furnace works continuously, the molten material being tapped out and fresh material charged as required. Polyphase currents used in this connection have the advantages that practically the maximum voltage of the generator is always maintained along one path through the material under treatment, the working current thus being the maximum current of the generator all the time, instead of varying from zero to a minimum. The total cross-section of the electrodes can also be smaller than for a furnace of the same capacity using single-phase current, and any electrode may be removed and replaced without interfering noticeably with the operation of the furnace. The advantages of the direct current are claimed to be retained, without the disadvantage of the electrolytic effects which always accompany its use. The source of the current may be a transformer with a number of separate windings, one end of each winding being connected to a common point, and the other one to one of the electrodes. It is claimed that the distinguishing feature of the invention is the use of a source of current having a star winding, and the provision of a neutral or common electrode in contact with the body to be heated. It is also claimed that a body of carbide forming materials or other charge may be heated to a temperature sufficient to effect the desired reaction, by employing a layer of molten iron rod or carbide of iron placed in the lower part of the furnace, and causing the various phases of the current to pass from terminals placed around and in contact with the iron to the central electrode, the iron thereby acting as a resistance conductor.

Apparatus for Electric Heating.—W. S. Horry, Niagara Falls, assignor to Union Carbide Company. Patent 771,250, October 4, 1904. Application filed June 28, 1904.

The furnace differs from the one described above inasmuch as it has no common terminal for the various phases of the polyphase current. Instead of that, the electrodes are distributed in one or more rows at equidistant points around the periphery of the furnace, and the terminals between which the maximum difference of potential establishes itself, are arranged at opposite ends of the diameter of the circle. The current, therefore, successively shifts between succeeding pairs of opposite terminals as the phases shift in the windings of the dynamo. As currents also flow across the furnace from each electrode to all others, the material lying within the path of the current is very uniformly heated. The furnace illustrated in the specification is stated to be intended for the production of calcium carbide, and designed to receive a current of 2000 kw. or more. It has two horizontal rows of electrodes, twenty-four in each row. A tapping hole is provided on a level with the bottom of the furnace. The production of carbide is continuous, the furnace has to be started in a manner similar to that decribed above.

Furnace for the Manufacture of Steel. Gustave Gin, Paris, France. Patent 771,872, October 11, 1904. Application filed June 30, 1903.

The furnace described in this application has already been made known to the elecrochemical world through articles by Mr. Gin, in which besides describing the furnace, he gives a good deal of theoretical information and elaborate thermochemical calculations concerning the processes which might be carried out in it. A lengthy abstract was given by Mr. Bennie, in Electrochemical Industry, Vol. II., page 20. The illustrations of the construction of the furnace which accompany the present specification, are exactly the same as those given in the latter article. Briefly recapitulated, the furnace consists of a movable truck, on which is placed the refractory hearth. Winding channels are arranged within the latter for the purpose of containing the fused metal which is to be treated in the furnace, and current is led in at the ends of this liquid column by terminals made of bowl-shaped, hollow and water-cooled blocks of steel. The hearth fits into an oven-shaped structure. Practical data as to the dimensions of such a furnace in practice, or its practical operation are not given; it is only stated that the pig iron is introduced in a liquid state through funnel-shaped openings provided in the roof for that purpose. It is claimed that any of the known processes for making steel can be used, and that the pig and scrap process can be easily practiced by adding to the melted pig iron the proportion of scrap which after being dissolved in the bath will give the right amount of carbon in the finished product. To any one who has seen the heterogeneous mass of iron rubbish of all kinds, called scrap, on the charging floor of an open hearth furnace, it would appear as though the melter and his helpers would have a good deal of difficulty in distributing that scrap evenly over the long narrow channels, so as to make a uniform reliable product. It is stated that the pig and ore process can also be used, and the addition of ore is made as in any other furnace in successive portions until the carbon is practically eliminated. The above remarks apply also to this process. A small opening is provided at the front of the furnace for raking off the

slag, but as the slag will form all over the long channels, it will require a good deal of hot work on the part of the melter to get it to the front.

Electrolytic Production of Metals and Compounds.

Manufacture of White Lead.—Jacques Oettli, Lausanne, Switzerland. Patent 771,024, September 27, 1904. Application filed July 6, 1903.

The process consists in the electrolysis of 1 per cent solution of common salt, which quantity must not be exceeded, since experience has proved that a more concentrated solution gives rise to other compounds. The electrodes are plates of lead, and the most suitable current density is 1 ampere per square decimeter. It must in no case exceed 2 amperes per square decimeter. A too great current density produces formation of compounds of lead resulting from the oxidation of the chloride, f. i., peroxide of lead, and through them of several oxychlorides of lead, the avoidance of which formation is important. The temperature of the electrolyte should not exceed that of the surrounding air, about 15 degrees C., as a higher temperature would probably lead to the formation of peroxides and oxychlorides of lead. The reactions taking place during electrolysis consist in the formation of chloride of lead at the anode by means of the chlorine liberated there. The chloride is transformed by the hydrate of sodium formed at the cathode into hydrate of lead, sodium chloride being reformed. The production of hydrate of lead is stated to be very rapid, and the anode is covered by a deposit, causing polarization. In order to prevent this deposit, and at the same time to use both electrodes, the current is reversed at short intervals, every five or ten minutes. Experience is stated to have shown that this method gives good results, both in regard to the quantity and the quality of the product obtained. Circulation of the liquid is necessary to keep the temperature of the electrolyte within the required limits. The hydrate of lead is carbonated by means of carbonic acid, and it is stated that the white lead is of better quality if the carbonation takes place at the moment when the hydrate is formed. It is, therefore, preferred to carbonate in the electrolytic tanks, carbonic acid being introduced into them until the basicity of the liquid begins to disappear, care being taken, however, not to neutralize the hydroxide completely. The liquid containing the white lead which settles at the bottom of the tanks is then syphoned off, the product is thoroughly washed and passed through a filter press and dried very slowly, the paste being first exposed to the open air (stretched on a large surface) and then finished in drying rooms by means of hot air, at a temperature not exceeding 50 degrees C. The theoretical voltage of decomposition of chloride of sodium is 4.2 volts, therefore, counting in the loss of resistance, 5 volts are required for every tank. The tanks are preferably of wood rendered water tight, and are preferably lined with lead. The lead electrodes are preferably cast plates on 1 cm. thickness and 1 square meter of surface. Badly refined lead, which contains iron, copper, arsenic or antimony, produces white lead of an inferior quality, contaminations of copper being especially to be avoided.

Manufacture of Zinc White.—Jacques Oettli, Lausanne, Switzerland. Patent 771,025, September 27, 1904. Application filed July 6, 1903.

The method depends on the electrolysis of a warm solution of sulphate of sodium, or of any other alkali salt of an acid, the zinc salt of which is soluble. The electrodes are sheets of zinc having a surface of 1 square meter and a thickness of 1 cm. The sulphate of zinc which is formed at the anode during electrolysis is precipitated by the caustic soda formed at the cathode, with the formation of hydroxide of zinc. This compound is separated from the solution by filtration, and is then dried and calcined in order to produce anhydrous oxide of zinc or zinc white. It is preferable to use a pressure of 2.5 volts, and a current density of 10 amperes per square decimeter, as with that current density an increase of temperature of the electrolyte is obtained, which is favorable for the precipitation of the hydroxide of zinc. The temperature quickly reaches 60 degrees C., and this is maintained by causing the liquid to circulate in the tanks. The product obtained is stated to be 1.5 grams ZnO per ampere-hour, from which a ton of zinc white in twenty-four hours is calculated to require 74 kw. or 96 ehp.

Process of Obtaining Metals.—F. von Kuegelgen, Holcombs Rock, Va., and H. Danneel, of Breslau, Germany, assignors to the Willson Aluminium Company. Patent 771,646, October 4, 1904. Application filed July 29, 1903.

The process is based upon the electrolysis of fused sodium chloride, fused either beforehand or by the current. An apparatus suitable for carrying out the process is illustrated in Fig. 2. It shows a cell, *A*, divided into an anode and a cathode chamber by means of a porous partition, *B*. The diaphragm is said not to be essential except to prevent the alkali oxide formed at the anode from going to the cathode. The anode, *C*, is preferably of carbon, and the cathode, *D*, is of iron. Oxide of tin is introduced into the cathode chamber if metallic tin is to be obtained. The sodium liberated at the cathode is claimed to combine with the oxygen of the oxide of tin. The tin thereupon is supposed to fall to the bottom of the chamber, while the sodium oxide formed in the above reaction settles on top of it. The chlorine is liberated at the anode and may be collected in any suitable manner. The minimum voltage which will be effective for the above operation has not been determined exactly, but it is stated to be lower than that required for the electrolysis of sodium chloride, namely 4.2 volts. The materials may be added in continuous streams, or from time to time in considerable quantities. Whether the above reactions will take place in such a matter of fact way as assumed in the specification is much to be doubted. The electrolysis of fused sodium chloride on a practical scale is a very difficult proposition, as has been found out by various people, among them the writer.

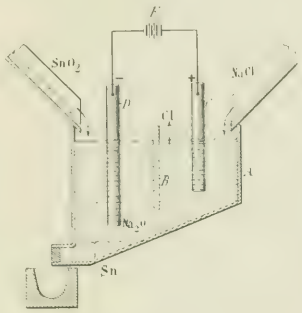


FIG. 2.—ELECTROLYSIS OF FUSED SODIUM CHLORIDE.

Apparatus for Mercurial Alkaline Processes.—C. W. Roepper, Germantown, Pa., and W. E. Harmon, Mechanics Falls, Me. Patent 771,833, October 11, 1904. Application filed January 30, 1903.

The apparatus belongs to that type of mercury apparatus in which mercury is transferred from the compartment in which it is charged with amalgam into another one where the amalgam is discharged, after which the mercury is again returned to the charging compartment. In its construction special attention has been paid to the control and the regulation of the circulation of the mercury in order to facilitate the reactions which take place in the two compartments, and to reducing the amount of mercury required in the apparatus as much as possible. The apparatus is a rectangular box, with a so-called main partition, which divides the anode from the cathode compartment. The partition reaches down into a groove in the bottom of the apparatus, so that a complete separation of the electrolyte from the caustic solution obtained from the discharge of the amalgam is effected. It

is stated to be important that the body of mercury or amalgam in the electrolytic compartment be comparatively thin and free from any waves or agitation, notwithstanding its circulation, and that the layer of mercury move evenly forward, and, although thin, be at no point broken. The bottom of the electrolytic compartment, therefore, is so constructed that it slopes up towards the main partition, by which means the maintenance of any considerable or stationary body of mercury in this department is prevented, while the amount of the metal necessary is reduced to a comparatively thin, wedge-shaped layer. The mercury, therefore, falls down as it passes under the partition, and this prevents any waves caused by the wheel, which accomplishes the circulation of the mercury from being communicated to the mercury in the electrolytic compartment by means of the groove. The bottom of the amalgam discharging compartment slopes down towards the wheel, in order to facilitate the circulation of the amalgam, as it is not necessary that the bottom of this compartment be completely covered with it. The discharge of the amalgam is effected by a series of discharging plates. The above mentioned wheel discharges the mercury into a narrow compartment, which is connected with a canal running along one of the longer sides of the box, which canal at the other end of the box enters another narrow compartment. The latter is separated from the electrolytic compartment by a partition, reaching down into a groove in the bottom of the box, and thus effecting a mercury seal as in the case of the main partition. Both of the partitions are traversed lengthwise by a pipe which is fitted with a series of apertures opening into the electrolytic compartment above the level of the mercury and spaced across the width of the compartment. The pipe towards the discharging end of the apparatus serves for the introduction of the electrolyte, while the one towards the other end serves for its discharge. The aperatures may be provided with aprons, which deflect the flow of the solution downwards. It is claimed that this arrangement distributes the flow of the electrolyte over the width of the compartment, and compels it to flow in the vicinity of the bottom edges of the anode plates, thus assisting in keeping the bottoms of the anode plates free from adherent gas bubbles. The apparatus gives the impression of being well thought out, and being based upon a thorough acquaintance with the conditions which have to be fulfilled in order to successfully accomplish the electrolysis of alkali salts with a moving mercury cathode on a practical scale.

Electroplating Apparatus.—Willis R. King, New York, assignor to the Hanson & Van Winkle Company. Patent 772,102, October 11, 1904. Application filed February 8, 1904.

The apparatus is designed for the plating of small articles, with a view to effect an improvement in the mechanical construction of such apparatus in general, and to accomplish the removal of the drum containing the small articles without disturbing or interfering with the driving mechanism or removing belts. The apparatus is also intended to buff or polish the plated surfaces of the articles. The drum in which the articles to be plated are contained, is made of a suitable non-conducting material, preferably of wicker work, and has the form of a basket or drum, provided with perforated wooden plates at the ends. It has a wicker work or other suitably constructed lid, provided with fastening devices. In the center of the drum there is arranged a shaft, which, by means of suitable mechanical devices is connected with the driving mechanism in such a way that it can easily be detached or inserted. A number of contacts are placed upon this shaft, which consists of a hub provided with several radially-extending straight or hook-shaped arms. The latter during the revolution of the drum are brought into constant contact with the articles to be plated, and as they are in metallic connection with the negative terminal of the dynamo by means of the central shaft and the suspension device, the articles are made cathodes and receive the deposit. The drum is suitably suspended into the apparatus by means of a supporting frame. The anodes are placed on conducting bars parallel to the long axis of the drum.

Electroplating Machine.—James Bailey, Walsall, England. Patent 770,148, September 13, 1904. Application filed February 14, 1903.

The essential feature of the machine is a traveling conveyor chain, which is driven in the horizontal plane a short distance above the surface of the electrolyte. Its mechanical construction is such that it can be readily adjusted, and eyes or recesses are provided in each link in which the work to be plated may be hung. After the work is thus connected it travels up and down continuously between four rows of anodes, the combined area of which is much greater than that of the work. It is stated that the plating is obtained very rapidly as compared with processes employed hitherto, and that on account of the constant circulation the deposit is found to be smooth and perfect, and not in the least granular. When the conveyor chain is once loaded with work, the process is continuous, and as plated work is removed, fresh work may be hung on.

Cleansing Sheet Zinc.—John Nelson, Peru, Ill. Patent 768,818, August 30, 1904. Application filed April 30, 1903.

The invention relates to means for treating sheet zinc preparatory to plating it. The inventor proposes to accomplish this purpose by connecting the sheets of zinc which are to be cleaned as cathodes in an electrolytic bath. As anodes he uses longitudinally-corrugated sheet iron plates. The tank in which electrolysis is carried out is of wood. The electrolyte is given as being of the following compositions: 1 gallon water, one-half ounce of potassium cyanide, 1 1-3 ounces sodium carbonate and 1 1-3 ounces lye (one-third ounce NaOH plus two-thirds ounce KOH). One gallon of four F ammonium hydrate is added to 150 gallons of the above mixture. The best results are stated to be obtained with a pressure of 7 volts, and for cleansing three pairs of sheets with six exposed surfaces of 3 feet by 7 feet, a current of about 400 amperes is required. It is claimed that by subjecting the sheets of zinc to electrolytic action in a bath of the above composition, they are thoroughly cleaned without having their polish destroyed, which would take place if the zinc were to be attacked by an acid.

Storage Batteries.

Secondary, or Storage Battery.—Carroll Potter, Philadelphia. Patent 769,403, September 6, 1904. Application filed December 21, 1903.

The object of the invention is to provide for guarding against accidental detachment of the plate lugs from their connecting strap, and to facilitate the operation of connecting the plate lugs and their connecting strap. For this purpose the plate lugs are provided with lateral projections, which have beveled or chamfered ends. Two of these projections are placed in alignment and burned together, thus producing a bridge piece. The burning is facilitated by the chamfering of the ends. The strap is provided with beveled or chamfered openings, through which the lugs are inserted and then burned and puddled in order to connect them. The bridge pieces are intended to impart mechanical strength to the structure and to prevent the lugs from working loose and becoming detached at the places where they are connected with the strap.

Secondary Battery. Lothar Fiedler, Stoke Newington, England. Patent 770,277, September 20, 1904. Application filed June 28, 1904.

The battery is constructed out of a series of trays with sloping sides, each being immersed into the one next below, with its bottom well below the level of the electrolyte contained in the lower one. The trays are shallow and composed of thin metal of an acid resisting nature, preferably lead. A lining is laid on the bottom of the trays, which consists of a

paste formed of finely divided zinc thoroughly amalgamated with mercury. The lining forms one electrode of the battery. Above the lining there is arranged an insulating support, composed of a corrugated and perforated plate of vulcanite, celluloid or similar material. This serves as support for a plate, which forms the positive pole of the battery, and which consists preferably of a lead grid, the spaces of which are filled with a paste of peroxide of lead. The electrolyte may be in a liquid or in a gelatinous condition. This construction is claimed to have the advantage of overcoming the disintegration which makes its appearance when vertical zinc

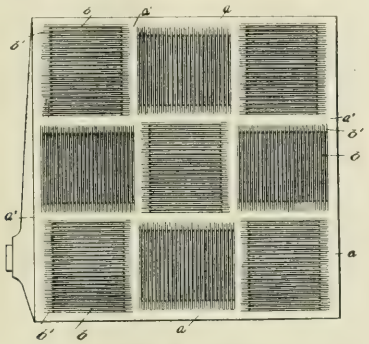


FIG. 3.—STORAGE BATTERY PLATE.

plates are employed, and which is due to the tendency of the amalgamated zinc to gravitate toward the lower portion of the plates, a tendency which is further promoted by the tendency of the zinc deposit on the plate, when the battery is charged, to be spongy.

Electrode for Batteries.—A. C. Wood and J. A. McMullen, Philadelphia. Patent 770,140, September 13, 1904. Application filed April 22, 1902.

The electrode is illustrated in Fig. 3. It comprises a sufficiently rigid framework, *a*, of lead or other suitable material, and a series of thin lead strips, *b*, arranged parallel to each other, and in groups separated from each other by means of the cross-pieces, a^1. The lead strips are spaced apart in order to insure a free circulation of the electrolyte and in order to facilitate their proper and uniform spacing apart, and to render it easy to set them in the mold, the end portion of each strip is bent back upon itself, as indicated at b^1. It is claimed that if a number of strips thus formed be arranged on edge and grouped together, they will support and properly space one another, and there is no necessity therefore of employing skilled workmen to set the strips and specially-devised molding apparatus to hold them. Adjacent groups of strips are disposed at right angles to each other. The strips *b* are notched at their ends, the notches being formed preferably in the thickened portions, and when the strips are set on edge, these registering notches form a channel which communicates with that of the adjacent group of strips. When the fluid metal is then run into the mold, the metal runs freely into the channel, and, fusing together with the contiguous portions of the ends of the strips, causes a perfect union of them. At the same time the fluid metal cannot enter the spaces between the strips, as the thickened ends of the latter abut closely. It is claimed that the spaces between the outermost strips of each group and the adjacent ribs are substantially the same as those between the strips themselves, and that the comparatively large open spaces, which have been incident to electrodes of this character, are thus entirely avoided.

Cell for Storage Batteries.—P. Figuccia, Boston. Patent 770,358, September 20, 1904. Application filed February 19, 1904.

The cell is rectangular in shape and provided with a lining of rubber, glass, etc. It is divided into a series of compartments by upright partitions of non-conducting material; the nature of the material is not stated. In each of these compartments are placed an anode and a cathode, which are kept apart by the interposition of a flat separator of thin wood, etc. The idea underlying the construction is the prevention of short-circuits caused by active mass dropping from the plates.

Lead Containing Cell for Secondary Batteries.—V. G. Apple, Dayton, Ohio. Patent 772,123, October 11, 1904. Application filed June 3, 1903.

The cell is made in one piece, and is provided with a number of parallel vertical interior ribs, which are integral with the walls and serve to receive and retain the active mass. The cell is made by softening lead and then forcing it into a mold under pressure. The inventor has found that it is possible to cast the lead in the softened condition which it assumes just before reaching the fusion point (approximately 620° F.), by employing a sufficiently great pressure. With the lead in a molten condition a pressure of 120 pounds per square inch produces good results for small cells, but the larger the cell to be cast, and the thinner the walls, the greater the pressure that must be employed. The inventor states that he is enabled to produce in this manner cell walls of much less thickness and correspondingly less weight than any other process of manufacture, as the cast wall can be made extremely thin,

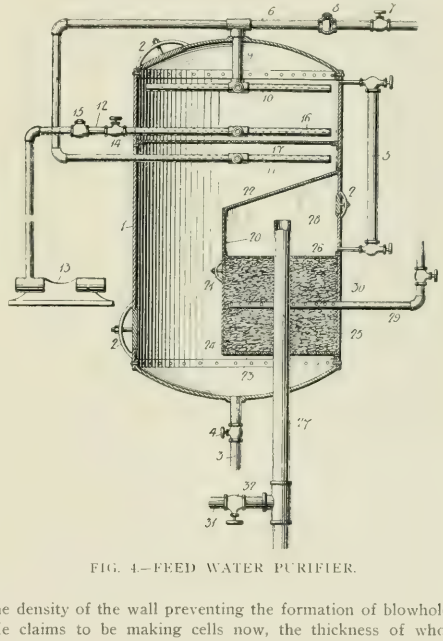


FIG. 4.—FEED WATER PURIFIER.

the density of the wall preventing the formation of blowholes. He claims to be making cells now, the thickness of whose walls does not exceed 1/32 inch.

MISCELLANEOUS.

Feed Water Purifier and Filter.—W. Dougherty, Chester, Pa. Patent 769,792, September 13, 1904. Application filed October 17, 1903.

The apparatus is illustrated in Fig. 4. It consists essentially of a drum 1, with hand holes 2 and provided with a steam pipe 6 and feed-water entrance pipe 12. A perforated diaphragm 17 is arranged within the upper part of the apparatus, which is made of equal parts of nickel and zinc, wherein the nickel is for the purpose of preventing a too rapid wasting away of the zinc. Other metals may be employed, but nickel is said to give the best results. It may also be made of galvanized

iron or woven wire heavily coated with zinc. The perforated cross 16 on pipe 12 is either entirely of copper or of iron, coated with copper. The galvanic action between the copper and the zinc is claimed to considerably increase the deposition of the solids held in solution or carried mechanically by the feed water. A filter box 20, filled with crushed flint or other non-absorbent filtering material 25, is supported upon the inside of the drum, and has a perforated bottom 23 and sides 24. The upper walls 20 and the top 22 are solid. The water passes through the filtering material and the perforated plate 26 into the upper part of the filter box, whence it is drawn off in a purified condition through boiler feed pipe 27. A perforated steam pipe 29 serves to clean the filter.

Water Purifier.—F. G. Kuné, New York. Patent 769,750. September 13, 1904. Application filed December 19, 1903.

The apparatus consists of a casting with an upper inlet and a lower outlet passage, which passages are connected by a number of tubular conduits. The whole is connected to one pole of a source of current. A cylindrical electrode is introduced through an insulating bushing into each of the above conduits. These electrodes are all connected to the other pole of the source of current. The water to be purified flows through the space between the cylindrical electrode and the conduit wall, and is subjected to electrolytic action.

Water Purifying Apparatus.—F. G. Kuné, New York. Patent 769,749. September 3, 1904. Application filed November 5, 1903.

The apparatus differs from the preceding, inasmuch as the successive conduits form a single line of pipe, each conduit being provided at its upper end with a T and at its lower end with an elbow. The tee of the first pipe is connected with the inlet pipe, and that of the last one with the outlet pipe, the tees, as well as the elbows of the intermediate ones, being connected by means of nipples. The pipes are parallel and preferably arranged vertically. An electrode is introduced by means of an insulating bushing into each of the pipes, and the water, as it flows through the system of pipes, comes successively under the electrolytic action between these electrodes and the walls of the pipes, the latter being connected to the other pole.

RECENT METALLURGICAL PATENTS.

Metals and Ferro-Alloys Free from Carbon.

It is well known that if carbon is used as a reducing agent for the reduction of metallic oxides for the purpose of producing either the pure metal or a ferro-alloy, the latter are never obtained free from carbon. It is, of course, possible to use somewhat less carbon than is theoretically required for reduction and to thus keep the content of carbon in the product down. But this has the disadvantage that part of the oxide which was to be reduced is lost, is slagged off; at the same time if the process is carried out in an electric furnace with carbon electrodes, the oxygen of the oxides exhibits its affinity for the latter and an unduly high consumption of electrodes results.

H. Goldschmidt has applied the most radical remedy, namely, to use aluminium, instead of carbon, as reducing agent; then no carbon can, of course, get into the product. In a quite different manner F. von Kügelgen and G. O. Steward (U. S. patent 771,645, October 4) try to overcome the difficulty. They conduct the electric furnace process in such a way that all the oxide is reduced and that the consumption of the carbon electrodes is a minimum; in other words, they do not care at first how much carbon they get in their product. But then, while their metal or alloy is still molten they bring it in contact with metallic calcium. This may be done by putting metallic calcium in the bottom of the tapping mold and tapping the furnace product onto it, or the calcium may be added while the metal is still in the original furnace. The calcium, by reason of its great affinity for carbon, forms calcium carbide which separates from the metal while the metal is still molten, and which rises to the top and is removed as slag. There is usually a small quantity of oxygen in the metal, and this will oxidize a part of the calcium, leaving only the remainder to unite with the carbon. It is, therefore, advisable to use an excess of calcium over that necessary to extract the carbon from the metal, the excess being proportioned to the oxygen content of the metal.

If the process should prove useful on a large scale, it would open the path for a new electrochemical product—metallic calcium; for there can be no doubt that calcium, like aluminium, will require for its manufacture an electrochemical method. Such methods were already noticed in our Vol. I, page 104, 143, 418, 422 and Vol II, page 276.

C. E. Manby (771,559, October 4) patents a steel alloy for which he claims great tensile strength, ductility and resiliency, and which is said to be particularly adapted for the manufacture of wire for musical instruments. Claim 1 reads, "as a new article of manufacture, steel containing nickel and ferrovanadium." The best composition is given as follows: "Iron, 78.10 per cent; nickel, 20 per cent; ferromanganese, 1.28 per cent; ferrovanadium, 0.62 per cent."

Utilization of Waste Furnace Gases.

The utilization of waste furnace gases is attracting more and more attention. The problem is to turn them to the best advantage in any given case. It was recently pointed out by W. R. Ingalls that processes which throw away great quantities of apparent value are not necessarily wasteful because they do so. Thus the waste of sulphur in burning sulphide ores is a waste if there is a market for sulphuric acid where such ores are smelted; but if there is no market, it may not be a waste at all. The utilization of the waste gases from blast furnaces for driving gas engines coupled to electric generators is now practiced on a large scale, especially in Europe; and there can be no doubt that in blast furnace works electrical energy is under all circumstances a most valuable by-product.

J. Herman (769,263, September 6) remarks that in copper matting and lead blast furnace practice at least three-quarter down to two-thirds of the carbon in the charge is burned to carbon monoxide; he proposes to pass the furnace gases through or over metallic oxides, such as roasted ore, in order to reduce the metallic oxides either to lower oxides or to the metallic state and oxidize the carbon monoxide to dioxide. "When desirable, the ore may then be reoxidized by the admission of air, and thereby adapted to do its work continuously for an indefinite period." The heat generated by the oxidation of the carbon monoxide may be used for heating air blasts for furnaces or for heating boilers, etc.

Even if the process can be made to work as the inventor desires, the figures given by him for the available heat are too high, since he entirely overlooks that energy is necessary for the reduction of the oxides.

Ore Draining and Leaching Tank

J. F. Webb (772,389, October 18) patents a tank for the rapid collection, drainage and treatment of slimes in cyanide mills, the particular object being to obviate the use of a filter process in the final treatment of slimes pulp. For this

purpose he uses a drainage and leaching tank having double walls and bottoms with an annular space between them, the outside shell having solid sides, top and bottom, with openings in it so arranged that it can be made air and water tight when under pressure, and the inner shell having its sides and bottom perforated and covered with suitable filtering material. Inside of the double walls and preferably in the center is a much smaller secondary hollow compartment or pressure stand-pipe, which is also perforated and covered on the outside with suitable filters to prevent it from being filled with slimes during the filling of the tank. This central pressure stand-pipe is connected at the top with hydraulic pressure pipes supplying either solvent solution or wash water, as required. It is also so arranged that the fluid pressure can be cut off and compressed air introduced into it and used in forcing the liquid contents in the pulp contained in the tank outwardly and downwardly through perforated sides and filtering material into the annular space between the sides and bottoms.

After separation from the sands, the slimes are run directly into the tank shown in Fig. 1, through the filling pipe 1. The liquid contained in the slimes then drains out through the filtering materials 3 and 4 and the perforated inner shell 5, and is caught and held in the annular space between the inner shell 5 and the solid shell 6, whence it runs out through the drainage pipes 7 and 8, and is pumped back to the usual storage vat. The filters 3 and 4 prevent the slimes from running through with the liquid, and they settle on the bottom of the tank until the latter is filled. The supply is then cut off and fresh cyanide solution is admitted into the central pressure stand-pipe tank. This is continued until the values are all dissolved, when the supply of solution is cut off. When the leaching is complete, compressed air is admitted into the perforated pipe tank, which results in compressing the pulp and squeezing out the solution. Wash-water is then admitted through pipe 10, and finally the leach pulp is discharged through the valves 17 and 18, in the botton of the tank.

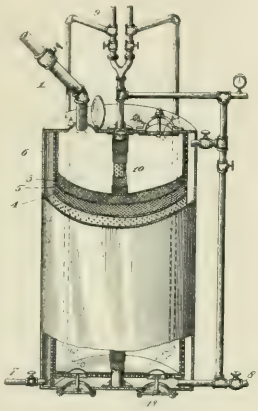


FIG. 2.—LEADING AND FILTERING TANK.

In amalgamating mills where the ore is crushed in clear battery-water, the tailings or slimes, after passing over the plates and concentrators, are run into the tank, the battery-water is washed out of them by compressed air, the solution admitted to the pressure stand-pipe, and the leaching and washing is proceeded with as described.

Miscellaneous.

O. Massenez (772,164, October 11) patents a process of dechromizing iron, in order to make it malleable. The main point is that when the metal is exposed to an oxidizing flame in the open hearth furnace, the chromic acid formed is absorbed by a slag which is easily fusible by itself, and that the amount of this slag is so proportioned that it contains less than 13 per cent of the chromic oxide.

G. L. Smith (771,675, October 4) patents details of construction of a crucible furnace with the use of gas or oil as fuel and the utilization of some portion of the waste heat in the waste gases.

J. A. Potter (769,712, September 13) patents an endwise-tilting furnace which is always connected at its higher and lower ends with the fuel supply and regenerator fuels, so that the higher portion of the furnace end and bottom are always exposed and highly heated.

J. Gayley (771,058, September 27) patents details of construction of apparatus for extracting moisture from air for blast furnaces or converters. The air is artificially cooled.

J. G. McGee (769,665, September 6) describes details of construction of a smelting furnace, with respect to water jackets surrounding the furnace, a wind jacket for supplying air to the interior of the furnace, and a water jacket for surrounding the slag spout.

J. W. Arnold (768,576, August 30) patents details of construction of a heating furnace by which the billets and bars of metal to be heated or re-heated are mechanically charged into the furnace, and can thus be charged either hot or cold.

A. Latto and J. C. Callan (772,723, October 18) provide means in connection with blast furnaces for catching and collecting the dust, dirt and fragments of ore which are discharged from the top of the furnace by the explosions incident to the operation.

M. Corcoran (769,689, September 13) patents details of construction of rabbles for use in calcining or roasting furnaces, in order to render the renewal of parts easy.

Feeding devices are patented by S. Forter (767,399, August 16, distribution of the charge for gas producers, blast furnaces, etc., toward the center and the sides); W. R. Reese (770,111, September 13, even distribution of the charge within a blast furnace); J. Roger (770,701, September 20, continuous and automatic feeding of ore to roasting furnaces); S. W. Vaughen, J. B. McClure and A. J. Boynton (768,207, August 23, blast furnace, top construction); and W. H. Freeland (768,596, August 30, delivering the ore or charge from stock piles, bins or bunkers to a point directly over the furnace).

F. O. Stromborg (771,681, October 4) patents a water-seal valve and valve-operating apparatus for regenerative furnaces; S. Stewart (772,846, October 18 a gas seal for metallurgical furnaces.

L. Silcott (768,546, August 23) described details of construction of a twyer iron; L. Keyling (770,910, September 27) a device for cooling the top gases, extinguishing the top flame and sparks and keeping the ashes back in blast furnaces. F. McCarthy (769,106, August 30) patents means for controlling and actuating the "notch-gun," whereby a single attendant may easily stop the "iron-hole" in a blast furnace after each cast.

C. Barber and G. L. Chase (769,584, September 6) patent details of construction of a waste trap for saving the precious metals contained in jewelers' waste.

O. S. Still (770,127, September 13) describes details of construction of a condenser for extracting mercury from ores.

Current Notes.

Artificial Rubies.—According to a recent consular report, artificial rubies are made by a process of the chemist Verneuil, by melting a mixture of clay and oxide of chromium at an even temperature of several thousand degrees. The two substances are carefully placed above each other in layers so as to prevent cracking the crystallized mass. It is stated that Verneuil finally succeeded in producing an artificial ruby weighing 5 pounds, which had a value of about $600. From this price it may be judged that the product is not first class, and probably just pays the costs of manufacture. In order to produce the exceedingly high temperature which is indispensable for success. Verneuil uses a blast of oxyhydrogen gas, which acts directly on the mass from the top. The hardness of the

ruby is the result of quick cooling caused by sudden interruption of the blast of oxyhydrogen. The artificial ruby is said to be very pure and brilliant, possessing all the physical properties of natural rubies. It can be cut, and takes a very fine polish. In this connection it may be mentioned that, in the manufacture of pure chromium by reduction with aluminium according to Goldschmidt's method, sometimes small crystals of rubies are formed. There is, of course, nothing surprising about this, since the ruby is corundum, colored red by traces of chromium.

Philadelphia Section American Electrochemical Society.—The Philadelphia members of the American Electrochemical Society held an informal meeting on October 7th, at the hall of the Engineer's Club, of Philadelphia, to discuss the arrangement of Section meetings for the winter. It was thought that a series of meetings "of the smoke-talk and 'round-table-talk fashion," would be the best plan for the coming season.

American Institute of Mining Engineers.—We have received from the Secretary's office package No. 5, 1904, of Institute pamphlets. It contains the following papers: H. M. Chance on the Taviche Mining District near Ocotlan, State of Oaxaca, Mexico; J. M. Clements on the Manufacture of Coke in Peru; E. A. Hersam on Testing Gold Ores by Amalgamation; S. H. Loram on the Gold District of Canutillo, Chile, S. A.; K. V. Norris on Centrifugal Ventilators; A. C. Spencer on Geology of the Treadwell Ore Deposits, Douglas Island, Alaska; G. F. Williams on the Genesis of the Diamond, and biographical notices of William Henry Pettee and Robert Henry Thurston, both being written by Dr. R. W. Raymond.

New Carbon Compound.—At a recent meeting of the French Academy of Sciences, M. Henri Moissan presented a paper concerning the preparation and characteristics of a new carbon compound containing molybdenum. According to a recent consular report, this compound is obtained by heating charcoal with melted molybdenum and aluminium in an electric furnace. The resultant metallic mass is treated with a concentrated solution of potash, and needles of well-defined crystals of the new carbon compound are obtained. The substance is very hard, is hardly attacked by acids other than nitric, and is not decomposed by water or steam at a temperature below 600° C. It resembles the carburet of tungsten, already known. It is thought that this new compound may play a role in molybdnum steels.

Proposed American Steel Plant in Canada.—It is reported that the United States Steel Corporation is seriously considering the establishment in Canada of a large plant for the manufacture of steel rails and steel generally. Its agents are collecting data regarding output, consumption, etc., as well as selecting a location for the proposed works. When this work is finished the question will be settled. The new duty of $7 a ton on steel rails completely shuts out the American rail manufacturers, and as the Canadian market is becoming a very important one the only way out of the difficulty is to build a manufacturing plant in Canada. Experts say that a plant such as the Steel Corporation would like to put up would cost from $12,000,000 to $13,000,000.

Book Reviews.

Electrical Influence Machines. By John Gray, New York: D. Van Nostrand Co. Price $2.00.

This book is a very complete description of the modern influence machines. The first part devotes itself to electro statics, while the influence machines are fully described in the second part. The author gives special attention to the modern machines and describes fully Varley and Toepler's, Holtz's, Wimhurst's, Lord Velvin's, Pidgeon's and compressed air machines, which are at the same time amply illustrated. The third section is devoted to the practical construction of Wimhurst's and Holtz and Voss's machines, the illustrations of this section being very complete and dimensioned.

ELECTROLYTIC PRODUCTION OF PHOSPHATE FERTILIZERS.

On page 65 of our first volume (October, 1902) we noticed a process by Wiborgh and Palmaer for manufacturing manure from apatite, or similar mineral phosphates. Further developments in the same direction are recorded in a pamphlet issued by Dr. Wlhelm Palmaer, from which the following information is taken. Dr. Palmaer is the director of the electrochemical laboratory of the Technical College of Stockholm, Sweden. The pamphlet is an account of his "electrolytic process for producing bicalcic phosphate for use as a fertilizer out of unserviceable raw phosphate."

It is a well-known fact that large quantities of raw phosphate occur, which are not available for the production of superphosphate, either by reason of their low percentage of phosphoric acid, or on account of other drawbacks attaching to them. That is the case with phosphorites and apatites containing less than 50 per cent of tricalcic phosphate, also with raw material containing a high percentage of iron, whether the iron occurs in combination with phosphoric acid or in the form of magnetite or haematite (in products of magnetic separation). The object of the Palmaer process is to produce at a profitable rate a satisfactory phosphoric acid fertilizer out of the above indicated raw products. The following data are stated to be derived from the experience gained with an experimental plant of a capacity of 6 to 8 electric horse power. The general features of the method are described as follows. "In an apparatus expressly adapted for the method, a solution of chlorate or perchlorate of sodium is electrolyzed. In the anode chamber an acid is thereby generated—chloric or perchloric acid—and in the cathode chamber a solution of caustic soda. The electrolysis is continued until a certain quantity of the dissolved salt has been separated into acid and alkali. The anode and the cathode solutions are led off into separate receivers. The acid anode solution is then allowed to work in a dissolving battery upon raw phosphate, in which process the phosphate is dissolved. Into the solution thus obtained the alkaline cathode solution is introduced, the whole being meanwhile kept vigorously stirred, until the liquid bears evidence of a slightly acid reaction; to obtain that result about half the cathode solution is required. In the process bicalcic phosphate is precipitated as a finely crystalline precipitation, which is drained off by filtration and washed. The filtrate, which contains 1-3 of the lime originally dissolved, but hardly any phosphoric acid, now had added to it the remainder of the cathode solution, whereupon the greatest part of the lime in the solution is precipitated as hydrate; by the introduction of some carbonic acid the rest is precipitated as carbonate; the lime precipitation is allowed to settle. The solution remaining above it is then drawn off. The original electrolyte is regenerated by its means and again enters the electrolyzing apparatus."

The process has been applied to the treatment of both phosphorites and apatites of various origin. The percentage of phosphoric acid varied between 9 and 40, corresponding to a variation of from 20 to 88 per cent of tricalcic phosphate, without having any effect on the course of the process. The raw material must be sufficiently pulverized, so that no grains of phosphate are embedded in silicates or other insoluble minerals.

"Out of the amount of acid generated per ampere-hour, 1.33 grams of tricalcic phosphate are stated to be dissolved. The voltage required is given as about 5 volts per cell. The phosphoric acid remaining in the solution after the precipita-

tion of bicalcic phosphate is about 1 per cent of that present in the raw material.

"Of the silicates or iron ore (oxides of iron) mingled in the raw phosphate, no appreciable quantity is dissolved. If the raw phosphate contains carbonate of lime, it is dissolved by the acid simultaneously with the phosphate, chlorate (perchlorate) of lime and carbonic acid being formed and the latter disappearing; consequently, the consumption of acid is rendered greater by the presence of the carbonate of lime, which is, from an economical point of view, a disadvantage. In this process one percent of carbonic acid in the raw material involves practically the same amount of consumption of acid, or of energy, as one per cent of phosphoric acid. On the subsequent addition, however, of the alkaline cathode solution, the same high-percentage bicalcic phosphate is precipitated. Consequently, an equally excellent fertilizer is obtainable out of raw phosphate containing carbonate as out of that free from it, though at an expenditure of more acid, or of more electric current. In any case, by the electrolytic method it will be possible to make use of raw phosphates containing more carbonate than is the case in the manufacture of superphosphate; on the other hand, they are not the most suited to be first resorted to."

With reference to the electrolyte to be used, the inventor states that it should be of such a nature that its acid (formed anodically) may yield, in conjunction with lime, an easily soluble salt, and of a kind which is not subject to change during electrolysis. "As electrolyte, solutions of perchlorate of sodium or chlorate of sodium are suitable, or else mixtures of those salts; the presence in small quantities of other salts, for instance chloride, is of no account. Both these salts are thoroughly suited to the purpose, perchlorate of sodium being the best that could be desired. Both chlorate and perchlorate of sodium are exceedingly easily soluble salts—1 part of chlorate of sodium being soluble in 1.05 parts of water at an ordinary temperature, while perchlorate of sodium is still more easily soluble; that is of importance, inasmuch as the washing of the precipitated bicalcic phosphate is thereby rendered considerably easier. A slight loss of the electrolyte by spilling in the process of washing, etc., always occurs. The amount of that loss will not exceed a value of $1.50 per ton of the finished article if perchlorate is employed."

The normal percentage of citrate-soluble phosphoric acid (P_2O_5) contained in the bicalcic phosphate produced by the electrolytic method, is stated to be about 34—irrespective of the character of the raw material. As the quantity of citrate-soluble phosphoric acid in the bicalcic phosphate obtained constitutes about 95 per cent of all the phosphoric acid in the product, the total percentage of phosphoric acid in the bicalcic phosphate works out at 35.8 on an average.

An account is given of experiments carried out by Prof. H. G. Söderbaum, chemist to the Swedish Royal Academy of Agriculture, with respect to the efficiency of electrolytic bicalcic phosphate as a fertilizer. The result of his experiments in cultivation is that the citrate soluble-phosphoric acid in the bicalcic phosphate proves to possess the same fertilizing value as the water-soluble phosphoric acid in the superphosphate, and consequently the same value as a trade product. Bicalcic phosphate can be employed as a fertilizer on all kinds of soil, even on sandy and boggy land, where superphosphate is out of the question. Bicalcic phosphate is also considered to be of excellent use in the manufacture of "complete fertilizers." Retrogradation of soluble phosphoric acid in the bicalcic phosphate, when stored, does not occur.

The question of cost of the process is, of course, of decisive importance. In this respect Dr. Palmaer gives the following data. 'One electric horse power produces in a year: 1.73 ton bicalcic phosphate, containing 36 per cent of soluble phosphoric acid; or 1.95 ton bicalcic phosphate, containing 32 per cent of soluble phosphoric acid.

"The percentage of soluble phosphoric acid will vary between 32 and 36 per cent, depending on the degree of desiccation, etc. But under given circumstances a product of uniform composition will be obtained with a percentage of phosphoric acid from 32 to 36 per cent. Ninety-five per cent of the total phosphoric acid will always be citrate-soluble. The cost for chemicals is small as they are regenerated. As a by-product will be obtained about one-half ton of very good lime for every ton of bicalcic phosphate.

"The capital needed amounts to about $65 per e. h. p. used in the manufacture, a plant of at least 2000 e. h. p. being supposedly employed. For manufacture on a larger scale the capital needed will be proportionately smaller. In this calculation it is supposed that the electric power is hired, and consequently the cost for the electric power plant is not included."

These last statements are not quite clear, but it would appear from this, that the figure, $65.00 per e. h. p., represents the first cost of installation and does not include the cost of operation. Of the latter, the cost of power would probably be an important item which may be calculated from the above data on the output of fertilizer per hp.-year. There would also be expenses for handling the material, etc., which cannot be exactly estimated from the data of the author. He points out that the freightage for a given quantity of phosphoric acid in the finished product is only about half that in the case of ordinary superphosphate.

A collection of samples of raw materials and products of this process is exhibited at the St. Louis Exposition in the Mines and Metallurgy Building, in Block 13.

PYROMETERS SUITABLE FOR METALLURGICAL WORKS.

(*Continued from page* 431.)

In the discussion of CALLENDAR & GRIFFITH'S pyrometers, thermo-couples, etc., in our last issue (page 432) the consideration of the resistance thermometer and its use for reading temperatures directly were described.

For recording temperature by means of an electric-resistance thermometer a Callendar recorder is employed. This instrument, which was designed by Prof. H. L. Callendar, consists of a Wheatstone bridge or potentiometer, in which the movements of the slider along the bridge wire is automatically effected by relays worked by the current passing through the galvanometer between the bridge-arms. According as the moving coil of this galvanometer is deflected in one direction or the other, a relay circuit is connected through one or the other of two electromagnets. Each of these magnets is mounted on a clock, the movement of which is prevented by a brake. When a current passes through a magnet this brake is lifted, allowing the clockwork to revolve. These clocks are connected by differential gearing with a recording pen, which is pulled in one direction or the other when the brake is lifted from the corresponding clock. The bridge slider moves with the pen and tends to restore balance. The thermometer employed in connection with the Callendar recorder is specially designed for measuring the temperature of annealing furnaces, and the recorder can be used for the determination of recalescent points, either by means of resistance or thermo-electric pyrometers. The direct-reading thermo-electric instrument consists of a sensitive D'Arsonval galvanometer, the coil of which carries a pointer reading on a scale divided in degrees Centigrade. By means of a simple switchboard several thermo-couples can be connected in turn with the galvanometer. The Callendar & Griffith's instruments are sold in this country by James G. Biddle, of Philadelphia.

3. *The Le Chatelier Pyrometer.*—At the instance of the Royal Physical Technical Institute at Charlottenburg, Mr. W. C. Heræus, of the firm of platinum refiners at Hanau, undertook the manufacture of a pyrometer according to the

principle of Prof. Le Chatelier, of Paris. The principle involved in the conversion of heat into an electric current and the determination of the degree of heat by a suitable device indicating the e. m. f. of such a current. A decided advantage which this pyrometer possesses over all others consists in its ease of application and convenience in handling, and in the fact that the temperature can be read off at almost any distance from the source of heat. The following is a description of the apparatus and of the method of operation: Two wires, one of absolutely pure platinum and the other consisting of the same metal alloyed with 10 per cent of rhodium, are fused together at one of their ends in the shape of a small ball (Fig. 1), and thus form a couple. This

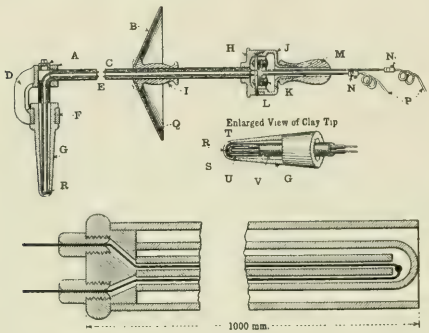


FIG. 1.—LE CHATELIER PYROMETER.

A. Interchangeable for Angular or Straight Connection.
B. Hand Screen.
C. Platinum.
D. Clamp.
E. Platinum Rhodium.
F. Hinged Cap locked by Cam Lever, quickly opened and closed for interchanging Clay Tip.
G. Fire Clay.
H. Terminal Box.
I. Hand-screen Handle movable on Pipe.
J. Terminal Box Cover.
K. Binding Posts.
L. Hard Fibre Disc.
M. Terminal Box Handle.
N. Wire Connector.
P. Copper Wires connected to Galvanometer.
Q. Asbestos Lining.
R. Junction of Wires.
S. Platinum Wire.
T. Platinum Rhodium Wire.
U. Internal Asbestos Lining.
V. External Asbestos Lining.

ball generates a slight electric current when heated, and, as ascertained by the Royal Physical Institute, by comparison with their celebrated air thermometer, such currents are proportionate to the heat applied. Each element is accompanied by a table of results determined in the same manner. To prevent injury to the wires by abrasion, injurious gases, and by alloying with other metals, they are usually enclosed in porcelain tubes, a small tube open at both ends being used to insulate the two wires and a large one, closed at one end, covering the whole. The Royal Porcelain Factory at Berlin prepares such tubes from an extremely refractory porcelain base, which resists a temperature of 2920° F. or 1600° C. These tubes can be made up to 50 inches in length. The galvanometer used in connection with the pyrometer is of the D'Arsonval type, and is especially adapted to the measuring of thermo-currents. The current is transmitted to an armature, wound in quadrangualr shape, through a fine wire of hard metal which does not oxidize. A small spring of the same material acts as a negative. A strong permanent magnet with iron pole shoes constitutes a magnetic field, and an iron cylinder in the center concentrates the magnetic lines of force. The pointer moves over two scales, one of which denotes the e. m. f. of the current in micro-volts, thus making it possible to check the readings of the instrument, while the second scale gives direct readings of the degrees of temperature. On the side of the cylindrical casing of each instrument there is provided an adjustable thumbscrew, which secures the armature, thus avoiding the breaking of its delicate suspension wire while in transit. The LeChatelier pyrometer is sold in this country by the representative of W. C. Heraeus, Mr. Charles Engelhard, New York City, as well as by Messrs. Eimer & Amend, New York City, and the Scientific Materials Co., Pittsburg.

(To be continued.)

LEAD-LINED VALVE IN BRASS CASING FOR HANDLING ACIDS.

The Schutte & Koerting Company, of Philadelphia, manufacture and have quite extensively in market a valve for the purpose of handling acids and other chemical solutions. It possesses all the features and merits that modern design can give.

The construction of the valve consists of a brass case, lined with lead, a yoke cover and spindle made of the best mixture of copper and tin; all parts being covered with lead which come in contact with the liquid.

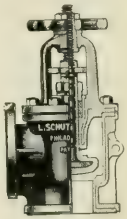


FIG. 1.—LEAD-LINED VALVE.

The valve is operated by a hand-wheel and spindle, the movement of the latter being straight up and down only. It is kept from turning by a slide fastened to the spindle, guided on the ribs of the yoke cover and a square milled on the spindle itself.

A stem nut is also provided and held in place by a jamb nut and shoulder. This stem nut revolves in yoke giving the spindle of valve its upward motion. As the stem is guided centrally at all times, there is no wear on these parts, however much the thread may wear. The upward motion, only, of the stem enables the valve to seat itself on the same identical spot at all times, thus reducing the wear and tear by friction to a minimum.

The process of molding these valves enables a smooth, uniform and uninterrupted surface to be obtained without further

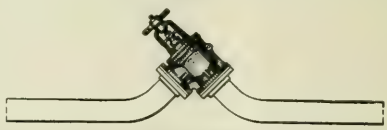


FIG. 2.—LEAD-LINED VALVE, USED IN A STRAIGHT PIPE LINE.

turning or finishing. The angle form of valve only is made, as shown in Fig. 1; while, when used in a straight pipe line it is conveniently attached, as indicated by Fig. 2.

DYNAMOS FOR ELECTROPLATING AND ELECTROTYPING.

The accompanying cuts illustrate a line of dynamos for the electrodeposition of metals, which the Bennett & O'Connell Company, 97-101 South Clinton Street, Chicago, Ill., has brought out.

The cuts illustrate a double commutator machine of 2000 ampere capacity, at six volts, running at a speed of 550 r. p. m. This type is built in sizes ranging from 1500 to 4000 amperes, and can be furnished with double voltages when so desired. The machines of smaller capacity are of the same general design, but have only one commutator. While the standard windings are for five volts, but can be furnished with a range of from 3 to 10 volts, and by means of special windings, any voltage up to 25 volts can be obtained. The machines are of slow speed design, and built for continuous duty, under a normal rise in temperature.

The magnet frames are of cast iron, of high permeability, with round poles of the best grade of forged steel, cast welded onto the frames, and are provided with cast iron shoes which serve to hold the field windings in position and to better distribute the magnetic flux over the surface of the armature, at the same time assisting in sparkless commutation, which is one of the features which the manufacturers claim.

This line of machines is compound wound, and operate at a perfectly uniform voltage from no load to full load without the customary shifting of the brushes to accomplish this result, and insuring a uniformity in the deposit on the articles which are being plated, thus avoiding the close attention of the operator otherwise necessary in order to accomplish this result. The compound windings consist of solid copper conductors and are mounted only on the two horizontal poles, while the shunt windings are uniform in size and strength and are provided on all four poles.

The armatures are of the ventilated type, with barrel windings, the core being formed with thin discs of sheet steel, of

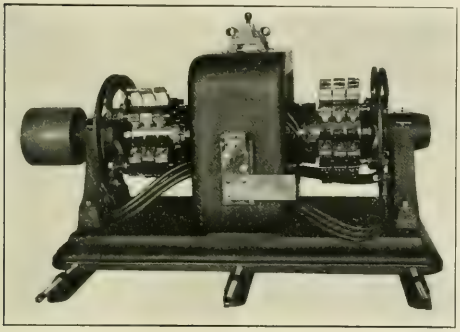


FIG. 1.—ELECTROPLATING DYNAMO

the best electrical quality, slotted on the outer periphery for the reception of the windings. The commutators are made of rolled copper bars, uniform in thickness and temper, which is a strong point in favor of sparkless commutation. The bars are held firmly in position by heavy cast iron flanges, in which no bolts are used, so that there is no tendency to work loose by expansion or contraction. The brush holders are of neat construction, so that they clamp the brushes firmly in the holders; they are also securely fastened to the stems and the brushes can be readily adjusted independently.

The brushes are of the laminated copper type, and do not cut the commutator. The construction of the rocker arm is

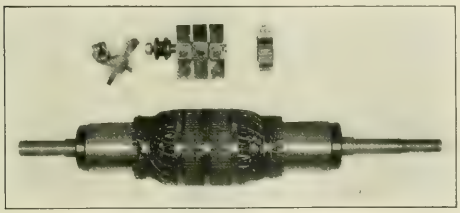


FIG. 2.—DETAILS OF CONSTRUCTION.

such that any individual set of brushes can be removed without disturbing either of the other sets. They are provided with cross-connections of solid copper bars, which are insulated from each other.

The striking feature in the design of these machines is the generous use of copper in all the parts carrying current, and the generous ratings in ampere capacity. The machines operate continuously under full-load capacity without injurious rise in temperature and without sparking in the brushes. They are tested up to 50 per cent overload for periods of from three to five hours, and are strong and substantially built.

These machines have oil reservoirs with ring oilers, which require little or no attention, and are provided with field-regulating rheostats, mounted directly on the frame of the machine, so that when they are driven it is only necessary to make the line connections and the machines are ready for service.

INDUSTRIAL NOTES

The AMERICAN SLATE COMPANY, of Boston, Mass., have removed to more commodious offices in rooms 629-632 Board of Trade Building, 131 State Street.

PRICES OF PLATINUM.—It is reported that the prices of crude platinum have been very materially affected by the drafting of the laborers from the Ural mines, owing to the Russo-Japanese war, and, notwithstanding recent advances, a further rise in prices seems almost assured.

CALCIUM CARBIDE.—According to the London *Electrical Review*, of September 30, the Usines Electrochimique de Halfslund is the title of a new company which has been registered at Geneva, with a share capital of $240,000 for the purpose of acquiring and working a calcium carbide installation at Halfslund, Norway. The composition of the Board of Directors shows that the Schuckert Co., of Nuremberg, Germany, which is already interested in two undertakings at Halfslund, is also at the back of the new company.

THE ELECTRIC SMELTING AND ALUMINUM CO., of Cleveland, Ohio, has acquired the business plant and equipment of the COWLES ELECTRIC SMELTING AND ALUMINUM CO., at Lockport, N. Y. The business at Lockport will be continued by the new company under the same management as heretofore (Mr. F. J. Davis, superintendent), but with the advantage of additional capital, better facilities, etc., for conducting the manufacture of the various alloys of aluminium, silicon, manganese, copper, sale of aluminium, etc. In the past both companies had about the same stockholders, but the Electric Smelting and Aluminum Co. held the patents and fought, as well known, to a successful issue, several famous patent litigations, while the Cowles Smelting and Aluminum Co. has been a manufacturing concern at Lockport.

MAGNESITE.—In a United States Geological Survey pamphlet, Mr. Charles G. Yale reports on the production of magnesite in 1903. The production in the United States continues to be entirely from California, and during 1903 the quantity reported was 3744 short tons crude, valued at $10,595, equivalent to 1361 tons calcined, worth $20,515. The demand for both crude and calcined is limited on the Pacific Coast, and, owing to a freight rate of $13 to $15 per ton on shipments to Eastern points, it is not shipped out of California, except to the paper mills in Oregon. The production of California could be quadrupled, if the demands of consumption warranted the increase. The imports of magnesite into the United States in 1903 amounted to 73,534,690 pounds ($311,396) of calcined, not purified magnesite, and 36,017,637 pounds ($150,002) of crude magnesite. Most of the imports came from Greece, although some came from Austria. The calcined magnesite, generally in the form of brick, is now universally recognized as the best material for lining basic open hearth furnaces, cement kilns, etc. It may be employed to advantage wherever high temperatures and chemical reactions are usually detrimental to dolomite, chromite, and silica brick. The distinctive characteristics of a magnesite lining are durability, freedom from moisture and silicic acid, and resistance to corrosion when exposed to the action of basic slags and metallic oxides. These qualities make the lining cheaper than most others in the long run. Thus far magnesite bricks have been made in California, though a factory for the purpose is shortly to begin operations at Oakland. The bricks made in this country come from the Fayette Manufacturing Co., of Layton, Pa., and the Harbison-Walker Refractories Co., Pittsburg.

PERSONAL.

Mr. John S. Peck, of the Westinghouse Electric & Manufacturing Co., has been appointed acting chief electrical engineer of the British Westinghouse Electric & Manufacturing Co. Mr. Peck entered the Westinghouse Co. a little over ten years ago, shortly after graduating from Cornell University. After a short time on the Student Course, he took up engineering work in connection with transformer design and soon became the head of the transformer designing department, which position he has held until the present time. The first signed article, published in the first issue of Electrochemical Industry (September, 1902), was from Mr. Peck's pen and dealt with transformer designs for electrochemical plants. He has contributed a number of valuable papers to the transactions of professional bodies, and taken leading parts in the discussions at their meetings. In this respect also his loss will be much felt.

Dr. Hans Goldschmidt, of Essen-Ruhr, Germany, the distinguished inventor of the aluminothermic process, has sailed for Germany, after having attended the International Electrical Congress. On the eve of his departure a dinner was given to him on October 14, at Delmonico's by Mr. Ernest Stütz, vice-president of the Goldschmidt Thermit Company, who had invited a number of friends of the inventor and his process. The following gentlemen were among them: Mr. R. D. Benson, vice-president, Tidewater Oil Company; Dr. C. F. Chandler, Columbia University; Mr. Hy. Des Anges, superintendent floating equipment, Long Island Railroad; Dr. Charles B. Dudley, chief chemist, Pennsylvania Railroad Company, Altoona, Pa.; Mr. Louis Fischer, United States Commercial Company; Dr. C. Kirchhoff, editor *Iron Age*; Mr. J. Newmark, United States Commercial Company; Mr. Mason D. Pratt, consulting engineer, Harrisburg, Pa.; Mr. W. Boardman Reed, engineer, maintenance and construction, New York City Railway; Dr. J. W. Richards, Lehigh University; Dr. E. F. Roeber, editor Electrochemical Industry, and Mr. Hubert E. Rogers, director, Goldschmidt Thermit Company. Dr. W. H. Wahl, secretary of the Franklin Institute, had sent his regrets to be unable to be present. In opening the series of informal speeches, Mr. Stütz gave an outline of the initial stages of the development of industrial aluminothermics in the United States. Interesting information was given by Dr. Dudley and Mr. des Anges on their results obtained with thermit repairs of broken locomotive frames and steamer shafts, and by Messrs. Pratt and Reed on rail welding. Dr. Goldschmidt spoke in a very suggestive way on the fundamental points of his process and on the developments of aluminothermics abroad, while Dr. Chandler gave some humorous reminiscenses of the day when the aluminothermic method was first exhibited at Columbia University.

DIGEST OF U. S. PATENTS

Prior to July, 1902.

Compiled by Byrnes & Townsend, Patent Lawyers, National Union Building, Washington, D. C.

Molten Electrolytes, Miscellaneous.

(*Continued from page 434.*)

462,567. November 3, 1891, Farnham M. Lyte, London, England.

Produces sodium or potassium carbonate and chlorin. Decomposes sodium nitrate by heating it with calcium carbonate; leaches out the sodium carbonate and converts the nitric oxide fumes into nitric acid by the action of air or oxygen and water; dissolves litharge in the nitric acid; precipitates lead chloride by sodium chloride; and finally fuses and electrolyzes the lead chloride to produce chlorin and lead, which is reoxidized. The electrolytic cell comprises a vessel and bell of enamel iron, or lined with or composed of graphite or earthenware. An anode of graphite depends into the bell, which has a chlorin outlet. A cathode of tinned iron extends through the bottom of the vessel, which has a tap-hole for the molten lead.

465,369, December 15, 1891, Ludwig Grabau, Hanover, Germany.

A cell for electrolyzing molten salts, especially of sodium, in which the electrodes are separated by a bell or "pole-cell." The bell has hollow walls of refractory material through which water or air is circulated, thereby chilling a protecting and insulating crust of the salt on the walls. The cathode is a depending iron bar, adjustably threaded through the top of the bell, its cross section and resistance being such that the current will heat it and maintain the sodium or other contents of the bell molten. The bell has a lateral outlet at its upper end for the sodium or other cathode product.

469,454, February 23, 1892, Augustus J. Rogers, Milwaukeee, Wis.

Closes the tap-hole of a crucible or other vessel for molten electrolytes by cooling and solidifying a plug of the molten electrolyte or deposited metal therein. A carbon resistance tube or rod extends loosely through the tap-hole. When the electric current is cut off from the tube or rod, the molten electrolyte or metal chills in the hole. The lower end of the carbon tube or rod may have a protruding metallic tube to assist in carrying off heat. To open the tap-hole, the tube or rod is heated by electricity until the plug is melted.

473,117, April 19, 1892, Paul Heroult, Neuhausen, Switzerland.

Reduces the resistance of carbon electrodes for use with molten compounds of aluminium, silicon, etc., by placing therein strips or rods of the metal to be recovered, or of an alloying metal. Vertical holes may be bored through the carbon and filled with cast metal; metal plates may be interposed between carbon slabs, or spaced carbon rods may be surrounded by cast metal.

475,498. May 24, 1892, Joseph C. Fraley, Philadelphia, Pa.

To produce iron castings free from strain and lines of crystallization, a helix of wire coated with refractory insulation is embedded in the sand around the mold cavity. Immediately after casting, a rapidly alternating current is passed through the helix and continued until and after the metal solidifies. Cylinders of solid iron or steel may be subjected to similar treatment as the casting, after being heated to a high temperature.

495,600, April 18, 1893, Gustaf O. Rennerfelt, Stockholm, Sweden.

A combined bell and cathode comprising a non-conductive wall and a conductive lining. The bell has a lateral outlet for the deposited metal, to which a suction pump is applied.

502,431, August 1, 1893, Henry H. Eames, Baltimore, Md.

Frees ores from sulphur, phosphorus, or arsenic by heating them in a vertical retort to a temperature below fusion, as cherry red, and passing an electric current through them between carbon-rod electrodes, which depend into the charge. The sulphur is discharged from the ore and falls to the bottom of the vessel, leaving a friable sponge containing the gold and other metals. A current of 15 amperes is specified. Five per cent of carbon may be mixed with the ore. Lime may be added to the charge to remove the sulphur as calcium sulphate.

503,451, August 15, 1893, Willard E. Case, Auburn, New York.

The cell comprises a flat bottom plate of conductive material, e. g., iron, serving as the cathode, and a cylindrical iron casing with a solid lining of salt. The salt may extend between the bottom and casing, to close the joint, or a ring of asbestos may be placed between them. The bottom plate may be protected from the heating flame by a lower layer of fireclay. The anode is a carbon rod depending into the vessel. The salt lining may be cast in a separate mold, may be cast between the iron casing and a temporary core, or may be chilled on the iron casing. The lining may consist of the single salt to be electrolyzed, or of one of the ingredient salts in a mixed electrolyte.

Electrochemical Industry

VOL. II. NEW YORK, DECEMBER, 1904. NO. 12.

Electrochemical Industry

Published on the first of each month by the
ELECTROCHEMICAL PUBLISHING COMPANY,
[Incorporated.]
114-118 LIBERTY STREET, NEW YORK.

J. W. RICHARDS, PH. D. .....*President.*
E. F. ROEBER, PH. D. .....*Editor.*

Telephone Call: 7607 Cortlandt.

Subscription Price: $2 per year, postpaid to any part of the world. Single copies 25 cents.

ADVERTISING RATES GIVEN ON APPLICATION.

Copyrighted, 1904, by the Electrochemical Publishing Co.

Entered as Second-Class Matter, June, 1903, at the Post-Office at New York, N. Y., under the Act of Congress, March 3, 1879.

CONTENTS.

Editorial 475
Our Second Volume 475
The Canadian Report on the European Electric Iron and Steel Furnace Processes 475
Aluminium 477
Laboratory Course in Industrial Chemistry 478
Local Sections of the American Electrochemical Society 478
Electric Furnace Processes for Iron and Steel Manufacture 479
Faraday Society Meeting 486
Electric Furnace Methods in Iron and Steel Manufacture in Comparison with the Ordinary Metallurgical Process. By B. Neumann 488
Materials for Resistors. By Francis A. J. FitzGerald 490
Flame Regulation in Chemical and Metallurgical Operations. By Carleton Ellis 495
Correspondence: The Limits of Physical Science. By Wm. A. Noyes 498
Synopsis of Articles in Other Journals 498
Analysis of Current Electrochemical Patents. By Geo. P. Scholl 503
Recent Metallurgical Patents 507
Current Notes 509
Book Reviews: Monographs on Applied Electrochemistry 510
Jahrbuch der Electrochemie 510
Pyrometers Suitable for Metallurgical Work 510
The Electric Production of Ozone and Sterilization of Water by Ozone 511
The Works of the Power and Mining Machinery Company 513
The Silent Chain for Driving Machinery 515
St. Louis Exposition 516
Industrial Notes 516
Obituary: T. M. Drown 517
Personal 517
Digest of United States Patents Prior to July, 1902. By Byrnes & Townsend 517

OUR SECOND VOLUME.

The present issue, closing the second volume of this journal, is accompanied by the yearly index. We have tried to prepare the index with a great deal of care as to cross-references and general completeness; the idea has been that even the most useful technical information, when scattered throughout the columns of a periodical, must be considered as buried therein forever, if the index is not complete and handy. In comparison with our first volume, which covered 598 reading pages, our second volume is smaller in size, covering 518 reading pages. The reason is that the first volume was exceptional in extending over sixteen months, from September, 1902, to December, 1903, and thus containing sixteen numbers, while the present and our following volumes are running from January to December, thus containing twelve numbers. From the above figures, it will be seen that the reading matter of our first volume covered, in the average, thirty-seven pages per issue, in our second volume forty-three pages. This increase of about 15 per cent in the amount of reading matter furnished to our readers for the same price, is one instance of improvement that was aimed at, while a glance over our index will show, we hope, that we have been successful in covering the field so broadly and completely as to satisfy the needs of all interested in electrochemical and electrometallurgical developments and in any new and important advances made in chemistry and metallurgy in general.

THE CANADIAN COMMISSION REPORT ON EUROPEAN ELECTRIC IRON AND STEEL FURNACES.

In this number we publish a long abstract of the report issued in the first days of November by the Commission appointed by the Canadian Government to investigate and report upon the different electric furnace processes employed in the iron and steel industries, or in process of development in Italy, France and Sweden. Besides a voluminous appendix the report proper consists of three parts: First, the report of Dr. Eugene Haanel, Superintendent of Mines, and the head of the commission; second, the report of Mr. C. E. Brown, acting as the electrician; and third, the report of Mr. F. W. Harbord, the metallurgist of the commission. Summaries of the results of the investigation in form of conclusions are given by Dr. Haanel and Mr. Harbord. The report is certainly one of the most important publications ever issued by the Canadian Government. As a British contemporary puts it, it "stands a monument of legitimate government activity, directed with intelligence and achieving its goal." The goal of the work of the Commission was to establish facts as to the processes investigated. The report, therefore, as a whole, is chiefly descriptive. The Commission describes what they saw, the plants and the apparatus, many valuable photographs and drawings of the furnaces being included. They also describe

in great detail the original tests which they made in several cases, giving details of the raw materials used, the expenditure of energy, the output and the results of extended analyses and mechanical tests of the products. The plants visited by the Commission were Gysinge and Kotfors, Sweden; LaPraz, France; Turin, Italy; and Livet, France. Tests were conducted at Gysinge, LaPraz and Livet only. Practically all essential details of the description of plants and processes are known to the readers of this journal, for which the main point of interest, therefore, lies in the original tests made by the Commission. We need offer no apology for reporting on them, and especially on the extremely valuable metallurgical tests of Mr. Harbord, at unusual length. Those of our readers who want to look up the construction of one or the other furnace, should refer to the indices of our two volumes under Furnace, Electric, Iron and Steel. There is at least one electric furnace process—that of Girod—making special steels on a commercial scale not mentioned in the report.

In considering the results obtained in the tests of the Commission, we may first take up the preliminary question whether the electric furnace can be used to obtain from given raw materials the commercial products of the iron and steel industry. This question is answered completely in the affirmative by the tests of the Commission, as was to be expected. Steels of any composition can be obtained in electric furnaces of different designs. With respect to the smelting of iron ore, the tests show that the quality of the iron produced in the electric furnace depends upon maintaining the same conditions as in the blast furnace, the main difference being that electrical energy is used instead of combustion of carbon to produce the necessary temperature. The reactions in the electric furnace, as regards the reduction and combination of iron with silicon, sulphur, phosphorus and manganese, are similar to those taking place in the blast furnace. By altering the burden and regulating the temperature by varying the electric current, any grade of iron, gray or white, can be obtained and the change from one grade to another is effected more rapidly than in the blast furnace. However interesting these results are, they are of small importance compared with the fundamental commercial question of the cost of the electric furnace process. Any engineering problem has in the last end only one goal, that is to make as much money as possible. Considered from this point of view, careful distinction must be made between three main problems: First, the production of high-grade steels of crucible steel quality; second, the production of structural steel to compete with Bessemer and open-hearth steel; third, the reduction of iron ore to pig iron.

With respect to the manufacture of crucible steel, either in the induction furnace or in Héroult's and Keller's resistance furnaces, the conclusion reached by the Commission is that steel equal in all respects to the best Sheffield crucible steel, can be produced at a cost considerably less than with the old crucible process. The leading iron and steel journal of this country, in commenting editorially on this result, adds the following qualification: "But this is, of course, only the case where electric energy can be had cheaply." This statement does not seem to be well considered, and would probably not have been made had the writer analyzed the figures given in Mr. Harbord's report upon which the conclusion is based. The fact is that the item of electrical energy is of comparatively small importance in this special problem. In the comparison of the cost of the electric furnace process and the crucible process for making crucible steel, we have to place essentially the cost of electrical energy and labor against the cost of fuel and labor in pot melting. The chief point is that the labor charges, cost of pots, etc., will be considerably more with the crucible process than the labor charges and repairs with the electric furnace per ton of steel produced. The cost of electrical energy is only a small item in the total cost. Thus, in the Kjellin process (page 66 of the report) the cost of electrical energy for producing 1000 kgs. of ingots is $1.48 and the total cost $37.48. Thus increasing the cost of electrical energy by 100 per cent means to increase the cost of the product by less than 4 per cent. As Mr. Harbord puts it, the advantage in working costs with the electric furnace is so considerable that, under the same conditions as to labor, it should eventually supersede the crucible process, especially as there seems to be every reason to believe that the special alloy steels now being so largely introduced for high-speed cutting tools could be readily made in this furnace.

Concerning structural steel to compete with Bessemer and open-hearth steel, the conclusion of the report is that it could not be economically produced in the electric furnace. This conclusion agrees exactly with the status of the industry, since the electric furnace is nowhere employed to compete with Bessemer or open-hearth processes. However, most interesting is the reasoning of Mr. Harbord on which the conclusion of the report is based. Mr. Harbord says (page 74 of the report), "The Héroult furnace is extremely well designed, and I see no reason why furnaces up to 10 or possibly 15 tons should not give satisfactory results; but at present I should hesitate to recommend larger furnaces than these." For small size electric furnaces there is a balance in favor of electric smelting compared with gas-fired Siemens furnaces of the same size, assuming the cost of materials and labor to be the same. But on the basis of the statement quoted above Mr. Harbord naturally reaches the conclusion that furnaces of this small size could not hold their own against gas-fired furnaces of 40 to 50 tons' capacity, or against the still larger furnaces of 100 to 200 tons, working on the Talbot system, where labor charges are reduced to a minimum. It is also true that in manufacturing on a large scale, pig ore and scrap would have to be used with a resulting greater consumption of electrical energy, while the fuel consumption is reduced in the large gas-fired furnaces. Nevertheless, the result of the Commission in this special point is essentially based on the present impracticability of constructing large electric furnaces for this purpose, while it appears that this difficulty is not inherent in the electric furnace as such, but may be overcome by judicious design.

Concerning the reduction of pig iron from ore, the conclusion is reached that the electric furnace can compete with the blast furnace only when electrical energy is very cheap and fuel very dear; on the basis of electrical energy of $10.00 per hp.-year, and coke at $7.00 per ton, the cost of production in the electric furnace is approximately the same as the cost

of producing pig iron in a modern blast furnace. This is Mr. Harbord's conclusion, based on the experiments made at Livet. It was impossible to make tests under more favorable conditions, since there is nowhere a plant reducing iron ore in the electric furnace to pig iron on a commercial scale. It is only fair that Dr. Haanel calls attention to the fact that the figures obtained in these tests were obtained in experiments made off-hand, so to say, in furnaces not at all designed for the reduction of iron ore. These tests really permit nothing more than to form a general opinion as to the commercial possibilities of the process, and we believe that the result as it stands will surprise even the best friends of, and believers in, the future of the electric furnace. We do not mean to say that the results prove that electric reduction of iron ore would be practical and economical in Canada with improved furnace design; the fact is that the results of the Commission do not allow to draw any exact conclusion as to this point, but it must undoubtedly be admitted that better results can be obtained with better designed furnaces.

Since the report was issued in the first days of November, our weekly contemporaries have already had the privilege of discussing it in their columns. Among the prominent technical journals of this country, we noticed two which have expressed editorially opinions on the report and the general problem. The leading iron and steel paper, to which we have already referred, says: "Above all, the fact is now made plain that thus far the adventurers in this new field of metallurgical work have accomplished nothing which even faintly suggests the revolutionizing of existing methods in the iron and steel industry." A prominent civil engineering peper considers the results concerning pig iron as "the most important conclusion of the report," and passes over the crucible steel question with seventeen words. We heartily disagree with our contemporaries. The introduction of the electric furnace into the iron and steel industries is controlled by the same common-sense and common-place principles as any other industrial development. There may be people who think that there is glory in attacking a position on its very strongest point, instead of selecting the weakest spot, but surely this is not good business. The introduction of the electric furnace has gone on exactly in the way logically to be expected.; the first application was to the ferro-alloy and crucible steel problems, there is later time to look out for other possibilities. Even if these other possibilities should not realize, the special steel field is wide enough, or we should rather say, it will undoubtedly become wide enough, just as the result of the electric furnace process. If Dr. Héroult can do what he claimed in his recent Congress paper—that at a cost of not more than 50 cents per ton, any steel delivered in molten state, such as tapped out of a Siemens furnace or obtained from a Bessèmer converter, can be converted into steel of any desired composition, containing not more than 0.01 sulphur and 0.01 phosphorus—he is justified in predicting a revolution in the uses of high-grade steels. If they can be had cheaply, they will undoubtedly be used much more extensively. The electric furnace will then work as an adjunct to the blast furnace, the Bessemer converter and the open-hearth furnace. The cost of electrical energy should not trouble our "conservative" contemporaries in this special case since the utilization of waste gases for driving gas engines, coupled to generators, is a combination which has already proven successful.

The make-up of the Canadian Commission was singular in one respect. It consisted of a mining expert, a metallurgist and an electrician who made the measurements, but no electric furnace specialist, as might, perhaps, have been expected in an electric furnace Commission. Probably the latter was omitted to prevent any criticism to the effect that the Commission was influenced by an "interested party." As it was made up, its report has been received on all sides as impartial. This make-up is also presumably the reason why the report is chiefly descriptive, and contains only occasionally notes as to improvements of furnace design. Instances are the low power factor of the Keller furnace, due to the iron casing, and the omission of the water-jackets around the electrodes in the Héroult furnace when visited by the Commission. The latter defect has been remedied in the meanwhile with remarkable results. There are undoubtedly other points in which the designs of some of the furnaces described could be improved. Here is a promising field for electric furnace designers.

◆◆◆

ALUMINIUM.

A discovery which may, in the next decade, influence to some extent the course of the aluminium industry, is the recognition that certain so-called clays, known for years in India as "laterites," are in reality more or less pure bauxites, some of them, the high-level deposits, being as pure as the best Arkansas or Georgia bauxites. Miss Buena Pool gave interesting details concerning this discovery, in a paper recently read before the Faraday Society at London and abstracted elsewhere in this issue. With the cheap labor of India, these materials can be mined and prepared at a very low cost. With the abundant water powers which the edges of the Deccan table-land furnish, there is no lack of power for the electrical purification and reduction of these ores. Considering the extent to which the metal workers of India, particularly of Madras, are importing sheet aluminium blanks and working them up into cooking utensils and military equipments, there is no doubt of the large market directly at hand for the aluminimum produced. Further, we believe that none of the present methods of preparing or producing aluminium have been patented in India, so that the development of the industry there appears to have before it a perfectly clear field, with a ready-prepared market for its product. Our English cousins, with a lien on India, so to speak, will be remiss if they overlook this combination of opportunities. Before dropping this subject, we will risk criticism by pointing the moral to adorn the tale. The moral is, do not take too much for granted. Because some geologist, very probably without making any test, called the laterites, in an offhand manner, clays, everyone else took it for granted that they were, until the open-minded discoverer, anxious to verify truth for himself, made an analysis and found they were something entirely different. Our compends of information are full of such misstatements, and discoveries are literally "under our noses" if we search honestly and without prepossessions.

LABORATORY COURSE IN INDUSTRIAL CHEMISTRY.

A paper on this subject by Prof. William H. Walker, of the Institute of Technology, of Boston, and originally published in the *Technology Review*, vol. VI., brings out forcibly some well-taken points with respect to university education of the future chemical engineer. Aside from familiarizing the student with some of those pieces of general apparatus which adapt themselves to reproduction and operation on a laboratory scale, there is not a great deal in a lecture course on industrial chemistry that can be efficiently emphasized by work in a laboratory. By his work in a laboratory devoted to industrial chemistry the student should gain a new point of view, or what might be termed the economics of chemistry, is to be studied.

Throughout the other work in his course, the student gives no thought to the relative cost of the material he uses. It is of no moment to him in analytical chemistry, for example, whether the reagent be cheap or expensive. If the analysis is to be completed, the reagent must be used. Likewise, if a precipitate is to be washed or a substance dissolved, water must be used, irrespective of its volume. If the resultant washings or solution be too dilute or of too great a bulk, the water must be driven off, regardless of the cost of evaporation. In industrial chemistry, however, a reagent may be used only when its cost does not raise the total expense of the process above a fixed maximum. A sludge or residue may be washed only to the point where the value of the material held in solution does not fall below the cost of driving off the water.

A valuable introductory experiment is the purification of common salt, the analysis of which is given, to be used in the electrolytic preparation of caustic soda and chlorine. This is interesting for several reasons. First, because salt sufficiently pure for commercial electrolysis is itself a very cheap material, and the cost of reagents used in purifying a crude salt may easily exceed this value; second, the mechanical difficulties of the process are small; third, the reactions involved are simple and easily controlled, and fourth, a good result may be demanded and obtained. Although the necessities of the case have been carefully explained, the student will almost invariably propose throwing out the iron and aluminium by means of ammonium hydrate, separating the calcium as oxalate, and the magnesium as phosphate. He is here using the knowledge gained in his study of qualitative analysis, and this is eminently desirable; but, although he knows a thing to be possible, he must also ask himself: is it practicable? It does not here occur to him that not only are these reagents very expensive, but that he is contaminating his salt with ammonium chloride.

It is usually a revelation to him to find that anything so "scientific" as a solubility table is of value in determining the volume of water necessary to handle a given weight of salt, that anything so unscientific as a Beaumé hydrometer is an instrument with which he must ultimately become familiar, that boiling off water is expensive, etc.

Whether such an experiment is considered successful or not depends not only on the purity of the product or the percentage yield, but upon the cost of the finished product as determined by the cost of the original salt and the materials used in its purification. The statement of the results of the operation should show the weight of salt taken, the amount added in the form of reagents, the amount returned to the system as mothor liquor, that sent back to the water supply in the form of wash water from the various precipitates, and the weight of pure salt recovered either in the form of brine, as determined by its density, or recovered as pure crystal salt. Great care should be taken to impress upon the student that the value thus obtained does not represent the manufacturing cost of the purified salt; that the very important factors of labor, interest on investment and depreciation of plant have not been included.

The influence of the mechanical difficulties inherent in carrying on a given process as contrasted with the cost of raw materials is well shown in the preparation of barium nitrate by two different methods.

The laboratory has, of course, its limitations, and in determining the depreciation of the apparatus used in a given operation, this limit is very soon reached. Such matters as labor, cost of plant, interest on investment, insurance, etc., do not lend themselves at all to laboratory treatment. On the basis of the experiments, however, they can be discussed in conference with greater profit and to a much better advantage than if the laboratory work had not previously been done.

In addition to acquiring a general idea of what the factors are which enter into an industrial problem, the student may at the same time have awakened in him an interest in what has been termed the "spirit of research." The conditions influencing or controlling the result may be systematically varied in such a way that each man or group of men will, in performing the experiment, contribute data toward its solution. A good example of this idea may be found in the electrolysis of brine for the production of bleaching liquor.

Dr. Walker emphasizes the importance of the preparation of a written report upon some problem, the solution of which has been attempted in the laboratory—such a report as the chemist of a works would be expected to make to its superintendent. The student should also thoroughly understand the value of a well-known note-book, not only as a record of experimental data obtained, but as legal evidence in case the matter contained therein becomes the subject of litigation.

As a further advantage possessed by a course in industrial chemistry, though in no way limited to it, may be mentioned a certain mental stimulus which it furnishes to original, independent thinking. Even though the subject of mental discussion be the same, if the point of view be changed, the mind is refreshed. If, for example, after studying the speed of migration of the ions and their transference numbers as a problem in theoretical chemistry, the same subject be taken up in an attempt to increase the concentration of caustic soda in the effluent from an electrolytic cell, the student can work with greater mental vigor than if he continued to think upon the theoretical problem alone.

Dr. Walker concludes that such a course, as outlined above, will never take the place of an apprenticeship in a factory or works—will not make a finished engineer, but it will contribute toward giving that method of thought and work which produces the man "who knows what to do when there is something to be done."

LOCAL SECTIONS OF THE AMERICAN ELECTROCHEMICAL SOCIETY.

The Philadelphia and Madison local sections of the American Electrochemical Society have started the work of the season.

On a preliminary meeting of the Philadelphia section we reported last month. In the meanwhile, the first meeting has been held in an informal and very satisfactory manner, the subject of the discussion being electric furnace methods in iron and steel industries. Mr. S. S. Sadtler and Dr. Geo. P. Scholl reported on special points on new developments in this line, and an informal and animated discussion followed.

The local section at Madison, Wis., held its first meeting on Nov. 21 and re-elected as officers for the coming year: Prof. C. F. Burgess, chairman; Mr. F. L. Shinn, secretary and treasurer. Dr. Kahlenberg addressed the meeting upon electrochemical features at the recent International Congresses at St. Louis. It was decided to hold meetings each month during the college year.

ELECTRIC FURNACE PROCESSES FOR IRON AND STEEL MANUFACTURE.

The full report of the Commission, appointed by the Canadian Government to investigate the different electrothermic processes for the smelting of iron ore and the making of steel in operation in Europe, has just been issued. Since we have repeatedly referred in our columns to the work of this Commission, we will give here only a summary of the report, with special references to those points which are new in it.

The report covers 223 pages and is typographically very handsome, well printed and profusely and nicely illustrated. Besides the full account of the tests made by the Commission and the results obtained, the report contains, in the description of processes, much information which was heretofore available in scattered form only. For this reason alone, it is very valuable, and will remain for some time to come the handiest source of information for those interested in the subject.

The first part of the report gives descriptions by the chairman of the Commission, Dr. EUGENE HAANEL, of the Kjellin, Héroult, Stassano and Keller processes, and short notes on the Harmet and Gin processes. All essential points brought out in this description have already been noticed in our columns. The descriptions in the report are given in a concise and clear way, with valuable detailed drawings of the furnaces employed.

This part of the report is concluded by the conclusions reached by Mr. W. F. Harbord as the metallurgist of the Commission, to which Dr. Haanel adds some notes. These will be given below in connection with Mr. Harbord's report.

REPORT OF ELECTRICIAN.

The second part of the volume is the report of the electrician, Mr. C. E. BROWN, who gives a full account of the measurements of the electrical energy made in the various furnace plants visited. A summary of his results is given as follows. For the horse-power-year, in all cases, a year of 365 days of twenty-four hours is assumed, and where the power is employed a smaller number of days, the cost must be corrected accordingly. The costs are based on a rate of $10 per electric horse-power-year.

SUMMARY OF RESULTS OBTAINED FOR STEEL.

	Kjellin Process.		Heroult's Process.			Keller Process.
	Charge No. 546.	Charge No. 547.	Charge No. 658.	Charge No. 660, Tool Steel.	Charge No. 660, Structural.	
Total kilowatt hours	857	994	1,410	2,580	1,680	1,325
Total-horse-power, years	1,133	0.154	0.219	0.40	0.261	0.206
Output of ingot in kilograms	1,030	955	1,283	2,341	2,341	1,650
Killowatt hours per ton of ingot	832	1,040	1,100	1,100	718	804
Horse.power-years per ton of ingot	0.13	0.16	0.17	0.17	0.111	0.125
Cost of electric energy per ton of ingot at $10 per h. p. year	$1.30	$1.60	$1.70	$1.70	$1.11	$1.25

SUMMARY OF RESULTS OBTAINED FOR PIG IRON.

	Heroult Process.	Keller Process.	
		First Run.	Second Run.
Total kilowatt hours	3,280	33,700	10,840
Total horse power, years	0.51	5.23	1.69
Total output of pig iron in kgs	969	9,868	6,692
Kilowatt hours per metric ton of pig	3,380	3 420	1,620
Horse-power-yrs, per metric ton of pig	0.525	0.53	0.25
Cost of electric energy per metric ton of pig at $10 per h. p. year	$5.25	$5.30	$2.50

With respect to the above figures, the following remarks may be made. For the test of the Héroult process for pig iron a voltmeter and ammeter were used. "No determination of the power factor could be obtained, but a value of 0.75 would appear to be reasonable, and is assumed for purpose of calculation."

The first run of the Keller process for making pig iron was made with furnaces Nos. 11 and 12; the energy was measured by a recording wattmeter and the power factor determined by means of an oscillograph. The second run was made with furnaces 1 and 2 and electrical readings were taken on the switch board voltmeter and ammeter, which were afterwards calibrated, and the power factor at the electrode was determined by means of the oscillograph. It will be observed that the consumption of electrical energy per ton of output, is less than one-half as great in the case of furnaces Nos. 1 and 2 (second run) as in furnaces Nos. 11 and 12 (first run). "This great variation is not to be ascribed to any material difference in design or construction, but rather to the conditions of operation. The power factor for furnaces Nos. 11 and 12 is fairly low, and for Nos. 1 and 2 extremely low. This is doubtless due mainly to the iron casing which forms a magnetic circuit around each shaft of the furnace, and is highly magnetized by the large current giving to the circuit a very high reactance. In case of the erection of a new plant, this iron casing would be omitted between the two shafts, or entirely. Either change should result in a very great improvement of the power factor, and a corresponding diminution of the kilo-volt-ampere input required, and give very much better conditions of operation for the alternator. A further improvement of the power factor would be effected by using current at 25 cycles. There seems to be no inherent reason why a reasonably high power factor cannot be obtained by careful attention to all of the details of design affecting the electric circuit."

Charge No. 546 of the Kjellin steel process was for making one per cent carbon steel, charge for 547 for making 0.4 per cent carbon steel. (See the metallurgist's report below.) Concerning the Kjellin furnace, Mr. Brown makes the following remarks: "The principal disadvantage, electrically, in this system is the very low power factor obtained, resulting from two causes, namely, the very high self-induction of the secondary due to its wide separation from the primary by the furnace wall and ventilating space, and its low resistance. In the present case, with a periodicity of 13 to 14 cycles, the power factor is only slightly above 0.6 at full load, and with increased capacity the resistance will be reduced, while the inductance remains about constant, giving a still lower power factor, or requiring a lower frequency.

"Mr. Kjellin has calculated that for a furnace of 15 tons capacity per charge, it would be necessary to reduce the periodicity to about 4 cycles per second to get a power factor of 0.6, or that for three such furnaces, surrounding the three legs of a three-phase transformer, and made common in the center, with a joint capacity of 45 tons, the same frequency would be required. This extremely low periodicity, combined with a low power factor, will make the cost of generators much higher than for standard machines.

"The system has, on the other hand, two important advantages. First, that it takes current directly at a voltage suitable for generation and transmission over distances, the 3000 volts here used being capable of increase to 5000 or 6000 volts, where required, which should be ample for any case arising in this class of work; and, second, that no cables, connections, or electrodes, with their attendant cost, loss of power and necessity of attention, are required in the secondary circuit, and for large furnaces, using currents from 10,000 to 30,000 amperes, this is an important item."

REPORT OF METALLURGIST.

The third part of the volume comprises the report of Mr. F. W. Harbord, the metallurgical expert of the commission. Since it contains much exact information on the composition of the products of the various furnace processes, we will abstract it at greater length.

KJELLIN PROCESS.

The raw materials used in Gysinge are best Swedish pig iron (Dannemora) and bar scrap Walloon iron of the fol-

lowing composition. The pig iron contained 4.400 per cent C, 0.080 Si, 0.015 S, 0.018 P, 1.000 Mn, 0.015 Cu, 0.035 As. The Walloon bar iron contained 0.200 per cent C, 0.030 Si, 0.003 S, 0.009 P, 0.120 Mn, 0.008 Cu, 0.035 As.

The furnace is never completely emptied. Approximately 700 kg. are always left in it, the furnace men having instructions always, as far as possible, to leave the same quantity in the furnace.

The first experimental charge (No. 546) was arranged so as to produce a high carbon steel containing about 1.0 per cent of carbon. For this purpose the charge was made up as follows:

	Kilograms.
Pig iron (white)	300
Steel scrap	125
Bar scrap	600
Metal in furnace, estimated	700
Silicon pig, 12 per cent	30
Ferro-manganese, 80 per cent	1
Total charge	1,756

The steel scrap was from previous charges and contained about 1.0 per cent of carbon. Only a part of the materials was charged at the commencement, but as the charge melted, further additions of pig iron and scrap were made. The bar scrap iron was more or less rusty, and consequently had some oxidizing action upon the impurities in the pig iron; as the furnace is never completely emptied, the slag from previous charges gradually accumulates, and is removed in small quantities, from time to time, from the top of the bath of metal. About 7 kgs. of slag, somewhat ferruginous, were removed during the working of this charge. Assuming that no oxidation had taken place during melting, the steel should have contained about 1.40 per cent of carbon, but owing to slight oxidation, the actual percentage was 1.082.

When the entire charge was melted, the current was continued until the temperature of the bath had acquired the necessary temperature for tapping, and the steel was then tapped into a ladle in the usual way and cast into ingot molds. The time taken for the working of the charge was six hours. The metal ran from the ladle quite freely, and no skull was left behind. It was very quiet in the ingot molds, and the weight of ingots was 1030 kgs., or 2271 pounds.

Drillings were taken from three 5-inch ingots and one 7½-inch ingot at top, center and bottom, and reserved for analysis. The analysis of an average sample is 1.082 C, 0.194 Si, 0.008 S, 0.010 P, 0.240 Mn, 0.012 As, 0.031 Cu, trace Al.

Analyses of drillings from top, bottom and center of various ingots will be seen from the following to be almost identical:

	Drillings from Top Bottom and Centre of 7½ in. Ingot.			Drillings from three Separate Ingots, Nos. 1, 2 and 3.		
	Top.	Centre.	Bottom.	No. 1, Top.	No. 2, Centre.	No. 3, Bottom.
C....	1.083	1.077	1.050	1.086	1.086	1.070
Si....	0.194	0 205	0.196	0 206	0.204	0.205
S.....	0.008	0.010	....	0.009	0.010	....
P.....	0.009	0.011	0.011	0 010	0.011	0.009
Mn ..	0 242	0.260	0.250	0 250	0 246	0 250

The energy consumed was given above in the report of the electrician.

The second experimental charge (No. 547) was arranged so as to make a medium carbon steel of about 0.5 per cent carbon. Besides the 700 kgs. of steel remaining in the furnace, the charge was made up as follows:

	Kilograms.
Pig iron	100
Bar scrap	825
Steel scrap	100
Ferro-manganese, 80 per cent	1
Silicon pig, 12 per cent silicon	35
Total new charge	1,061

Eight hundred and seventy-six kilograms of ingots and 79 kgs. of scrap were produced. The analysis of an average sample being 0.417 C, 0.145 Si, 0.008 S, 0.010 P, 0.110 Mn, 0.020 As, 0.032 Cu, trace Al.

It was then decided to make a cast of low carbon (0.20 per cent or less) steel. But there were difficulties in getting a good tapping heat, on account of the limited amount of power available at the works. Owing to the deficiencies in power, it was most difficult to obtain the necessary temperature for tapping, in a reasonable time, with the result that the metal was kept in the furnace for from 1½ to 3 hours longer than it should have been, exposed to the action of the oxidizing slag. Another difficulty was that the furnace, having been designed especially for the manufacture of high carbon steels suitable for tool purposes, no slag hole for the withdrawal of the slag had been arranged for, as it had been found that in making these high carbon steels the small amount of slag produced could easily be removed through the charging doors. In making the soft steel, however, far larger quantities of slag are produced, and it was not found possible to remove the slag from the top, with the result that considerable difficulty was experienced in producing dead melted metal. Given a furnace slightly altered, so that the slag could be removed from time to time, and ample electric power to produce the necessary temperature rapidly, there is not the slightest doubt that dead soft steel could be satisfactorily produced.

As regards the mechanical and working properties of the steel produced, whether high or low carbon, there can be no question that the steel is of the highest quality. Experiments were also made at the Royal Arsenal, Woolwich, to test the capabilities of the steel when used for turning. The tools were all forged the same shape, particular care being taken that the tool angles were the same in each case. For comparison tests were made with similar tools forged from the best crucible steel used at Woolwich, known as grade "A," and also with tools forged from Mushet's steel. The steel operated upon was untempered gun steel, containing 0.3 per cent of carbon. As compared with grade "A," the results show that, speaking generally, there is little difference between this and most of the steels experimented with. On the other hand, the material was not so good as the Mushet steel. "It is only claimed for the above steel that they are equal to the carbon crucible steels, and the comparison with Mushet's steel was made to see if they were in any way superior to the carbon steels. The special properties of high-speed tool steels are due to the steel being alloyed with special metals, and to a particular heat treatment, and from a metallurgical point of view there should be no difficulty in making these special steels in the electric furnace."

The cost of production necessarily varies with local conditions, such as the cost of labor, refractories, electrical energy, and pig iron and scrap. Each of these heads is therefore considered separately.

Labor.—There were five men and one boy employed on the furnace at Gysinge for each twelve-hour shift, the output being on an average 3000 kgs. per twenty-four hours. Mr. Harbord, however, remarks that there seems no reason why the size of the furnace should not be very considerably increased, and with furnaces of five to ten tons capacity the labor cost would be very greatly reduced. "Five men and one boy could do all the necessary work if they had a little assistance in charging on a five-ton or even a ten-ton furnace, without being in any way overworked."

Pig Iron and Scrap.—Since the actual cost of these materials will vary within very wide limits, it will suffice here to give

what is a typical or average charge to produce one ton of ingots:

	Pounds
Best pig iron	600
Best Walloon bar scrap	1,200
Best tool steel scrap	188
Silicon pig iron, 12 per cent silicon	60
Ferro-manganese, 80 per cent	2
Total weight to produce 1 ton	2,050

Refractory Materials and Repairs.—From Mr. Kjellin's works books, extending over a period of ten weeks, during which 309 tons of ingots were made, it is shown that the cost of cutting out old lining, relining furnace, all refractories (magnesite) and labor charges came to 60 cents per 1000 kgs., equivalent to 54 cents per ton of 2000 pounds of ingots produced.

Electrical Energy.—According to Mr. Kjellin's books, the energy consumed in producing 309 tons of ingots during ten weeks or seventy working days, was 41.3 e. hp.-years, costing $1.34 per ton at a cost of $10.00 per e. hp.-year. This agrees well with the figures given above in the report of Mr. Brown.

So far no special alloys for the manufacture of high-speed cutting tools have been made at Gysinge, but there appears to be no reason why this should not be done. The furnace is simply a large pot furnace, and has the additional advantage that there is not the slightest danger of the steel taking up sulphur during the process of melting, and by making suitable changes, steel of any required composition can be made.

In Mr. Harbord's opinion, the furnace would require considerable modifications before it could be conveniently used for the manufacture of mild steel to compete with the Siemens furnace, as the difficulty of removing the whole of the slag, while retaining a small portion of the metal in the furnace, would, he fears, be considerable, and he anticipates that repairs could not be so readily effected if the walls were badly cut by the slag, as in the case of an ordinary Siemens furnace. "Mr. Kjellin has, however, shown so much ingenuity in surmounting the difficulties in connection with the manufacture of high carbon steel, that, given the opportunity to experiment with a furnace on a reasonable scale, it is quite possible that he may be able to overcome these difficulties and make the manufacture of mild steel a commercial success. The process, as at present worked, is admirably adapted for the highest class of steel from pure materials, and the only objection to it is that it is limited to these pure materials, and can only be used where they are obtainable." Mr. Harbord does not think in its present stage of development it is adapted to treat ordinary pig iron and miscellaneous scrap of more or less irregular composition as the complete elimination of any impurities present could not always be relied upon. Under the special conditions existing at Gysinge and in some other places, it is capable of doing most excellent work, and is a most efficient and economical metallurgical appliance.

HEROULT PROCESS.

Concerning the results of tests of the Héroult process, made at La Praz, the following information is given.

The usual charge was about three tons, and consisted entirely of miscellaneous scrap, with suitable additions of ore and lime. As in the case at Gysinge, it was arranged to make steel of varying carbon content, and the first charge was a low-carbon steel for transformers. As only a small quantity of steel was required, an exceptionally small charge was made. The charge (No. 658) was as follows:

	Pounds.
Miscellaneous scrap	3,307
Iron ore	330
Lime	246

The scrap was charged with some lime and then additions of ore and lime were made from time to time.

When the bath of metal and slag was completely melted, the slag was poured off, great care being taken to remove the slag entirely; a new slag was then made by adding about 55 pounds of lime, 15.5 of sand, and 15.5 pounds of fluorspar. This was melted and kept in the furnace for some time, when it was poured off as completely as possible, the last traces being raked off the surface through the pouring door. Another addition of lime and fluorspar, etc., in the same proportion as the last, was then made to form a finishing slag to remove the last traces of impurity; about 1.5 pounds of ferro-manganese was added, and the charge was poured into the ladle, a little aluminium being thrown into the ladle before the metal was teemed into the ingot molds.

The furnace was ready charged at 7:45 p. m., and the current put on, and it was poured at 12:15; time, 4½ hours. The very short time taken for the operation was due to the smallness of the charge, and to the fact that no time was required for recarburizing the very low carbon steel. The steel, when teemed, ran from the ladle freely, no appreciable scrap being left behind; it was very quiet in the ingot molds, and the steel ingots were exceptionally sound for steel of this quality. The yield was:

	Pounds.
Ingots	2,820
Scrap	9

This is equivalent to 2338 pounds of scrap for every 2000 pounds of steel produced. The analysis of the scrap and steel was as follows: Scrap charged—0.110 C, 0.152 Si, 0.055 S, 0.220 P, 0.130 Mn, 0.089 As. Steel produced—0.079 C, 0.034 Si, 0.022 S, 0.009 P, 0.230 Mn, 0.096 As, trace Cu.

This was a special steel for transformers, and in it the welding qualities were purposely sacrificed in order to obtain the special qualities required by the electrical manufacturers. In other respects the steel gave excellent results; it forged remarkably well, without a trace of red shortness, and gave very good cold, bending tests. The electrical energy is consumed at the rate of 0.153 hp.-year per ton of steel produced.

The next charge (No. 660) was arranged to produce a high carbon steel. The same scrap was used, and the charge was as follows:

	Pounds.
Miscellaneous steel scrap	5,733
Ferro-silicon	19
Iron ore	430
Lime	346
Ferro-manganese	3.3

Commenced to charge at 11:40 a. m., current put on at 11:50, but all the current not on till 12:45; tapped at 7.4 p. m.; time, 8 hours.

The scrap and part of the lime were charged before the current was switched on, and the remainder of the ore and lime was added during the melting. After the charge was completely melted, the slag was poured off, great care being taken to remove it as in the previous charge, and a second slag was made by adding 88 pounds of lime and twenty-two pounds of sand, and twenty-two pounds of fluorspar. This was melted and removed, and a finishing slag formed by the addition of similar quantities of lime, sand and fluorspar. The charge was completely melted at 5 p. m., five hours and twenty minutes after charging, and if soft steel had been required, the furnace would have been ready to tap at this time.

The bath, however, had to be recarburized to the required point, and this was done by adding in the furnace "carburite," a mixture of pure iron and carbon, until the required degree of carburization was obtained, 19 pounds of 12 per cent ferro-silicon being also added at the same time. The charge was sampled in the usual way with a spoon ladle, and when the furnaceman was satisfied that the bath contained the required percentage of carbon, the metal was poured into the ladle, a little aluminium added, and the steel teemed into the ingot molds. The metal ran very freely, leaving no skull in the

ladle, was quiet in the molds, and forged extremely well in the press; the welding tests were very satisfactory. The yield was 5161 pounds, equivalent to 2000 pounds of steel ingots for every 2230 pounds of scrap and metal charged. The following is an analysis of the steel: 1.016 C, 0.103 Si, 0.020 S, 0.009 P, 0.150 Mn, 0.060 As, trace Cu, trace Al.

The electric energy used during the working of the charge was 2580 kilowatt-hours, equivalent to 0.395 electric hp.-years, equal to 0.153 electric hp.-years per 2000 pounds of steel produced.

Had this charge been required for soft steel, it would have been ready to tap at 5 o'clock, when the consumption of electric energy was 1680 kilowatt-hours, equivalent to 0.257 e. hp.-years, equal to 0.100 e. hp.-years per 2000 pounds of steel.

It will be noted here that, starting entirely with nearly carbonless scrap iron, the first product obtained is soft steel; to produce high carbon steel this has to be carburized by suitable additions. Consequently, the metal has to be kept longer in the furnace to produce high carbon steel than low carbon steel, and the consumption of electric energy is greater in the former than in the latter case. This is just the reverse of the method of working at Gysinge, where the time taken in producing soft steel is longer than for high carbon steel. The methods of working, however, in each case depend more upon the materials available than any other consideration, and there would be no difficulty in making high carbon steel without recarburizing, by melting down a suitable mixture of pig iron and scrap in the La Praz furnace; and, on the other hand, pure scrap could be melted down in the Gysinge furnace and recarburized at the end of the operation, if desired.

Concerning the cost of production in the Héroult process, the following data are given. The consumption in electrodes, when working continuously, was 500 kgs. per week, and 50 per cent of old material, costing two centimes per kg., was mixed with 50 per cent of new material, costing 10 centimes per kg., thus costing about 30.00 francs for an output of 30 tons of steel.

The average output per twenty-four hours was 4 tons; figures furnished by Mr. Héroult from his book showed an output of 120 tons for 30 days consecutive work, and he considers that he can make 150 tons in this time. The average time for each charge was nine hours, and there were 5 men employed on the furnace each shift, including the foreman. In these men are included the ladleman and pitmen. The repairs and renewals are somewhat heavy; burnt dolomite costing 3 francs per ton of steel produced, magnesite 1.5 francs and acid refractories, including roof, about 2.5 francs per ton, making a total of $1.40 per ton for refractory materials.

[In a statement printed in Dr. Haanel's report, Dr. Héroult says that since the Commission visited LaPraz the steel furnace has been materially improved by the addition of water-jackets round the electrodes. "The effect is this: The output of the crucible has passed from 4 tons to 7 tons in twenty-four hours. The absence of air is so complete that we obtain a certain percentage of carbide of calcium in the slag. The loss of raw material has also greatly diminished."]

Since any scrap is suitable for the process, the price of the raw material is never likely to be very high, and may, as a rule, be taken to be about the same price as pig iron delivered at the same place.

The cost, as regards materials and labor, will be practically the same as for a gas-fired Siemens furnace of the same size, making similar steel. Any difference in the cost will be due to the cost of electric energy and electrodes, as compared with the cost of fuel. Repairs will probably be higher, but not sufficiently to affect the cost of production. In a small Siemens furnace of this capacity, the fuel consumed would vary from 1000 pounds to 1800 pounds of good slack coal, *i. e.*, small coal, per ton of steel produced. Such coal would probably cost $5.00 to $5.50 per 2000 pounds in Canada, and assuming 1200 pounds to be used per ton, this would be $3.00 per ton of steel. The cost of electric energy, at $10.00 per e. hp.-year, would be $1.53, and electrodes are estimated to cost 20 cents, making a total of $1.73 against $3.00, so that there is a balance in favor of electric smelting, assuming the cost of materials and labor to be the same.

If the Héroult process is compared with the crucible process, the advantage in working costs with the electric furnace is so considerable that under the same conditions as to labor, it should eventually supersede the crucible process, especially as there seems every reason to believe that the special alloy steels now being so largely introduced for high-speed cutting tools could be readily made in this furnace.

How far this electric furnace can compete with the ordinary Siemens process under the conditions prevailing in Canada is a much more difficult question to decide, as the cost of production largely depends upon the output, and to get a large output with low labor charges means very large furnaces, as practically a 30 or 40 ton furnace requires hardly any more men than a 3 or 4 ton furnace, provided mechanical appliances are arranged for charging. Mr. Harbord thinks that the Héroult furnace is extremely well designed, and he sees no reason why furnaces up to 10 or possibly 15 tons should not give satisfactory results, but at present he hesitates to recommend larger furnaces than this. He does not think, therefore, that furnaces of this size could hold their own against gas-fired furnaces of 40 to 50 tons capacity, or against the still larger furnaces of 100 to 200 tons, working on the Talbot system, where labor charges are reduced to a minimum. Moreover, in making structural steel in large quantities, it would not be possible to get sufficient quantities of scrap so that pig, ore and scrap would have to be used, and this would take a longer time to convert into steel than scrap charges, and the consumption of electrical energy would be greater. On the other hand, in the large gas-fired furnaces, the consumption of fuel per ton of steel is reduced.

Brief notice is made of the Keller steel furnace which in principle is identical with the Héroult furnace and varies only in details of construction.

Mr. Harbord concludes that the Kjellin, Héroult, and Keller processes of electric steel manufacture "are all capable of producing equally good steel and the selection of one or the other would depend upon local conditions.

"The Kjellin process is undoubtedly the nearest approach to the crucible process, and given a high-class pig iron and scrap has much to recommend it, a special point being that the operation is conducted in a closed crucible or hearth, and there is no possibility of impurity being introduced by contact with electrodes. Its application, however, is limited, and, although some purification can be effected during the melting, the quality of the steel will largely depend upon the raw material being very pure, in the same way, although to a somewhat smaller extent, than in the crucible process. To what extent the phosphorus, etc., can be removed in this process our experiments do not enable us to say, as all the charges we followed were made from purest materials, but the furnace is more suitable for replacing the crucible steel melting than for dealing with miscellaneous scrap and pig iron similar to that used in a basic or acid Siemens furnace.

"On the other hand, furnaces of the resistance type, with electrodes, can treat phosphoric scrap and pig iron in the same way as a gas-fired Siemens furnace. The neutral atmosphere and the intense heat which it is possible to obtain enable very basic slags to be used, and the mechanical arrangements allow the ready removal of the slag so that a pure non-oxidizing slag to remove the last traces of phosphorus can be ensured at the end of the operation. This undoubtedly opens a larger field for the resistance furnace, as in many districts common scrap can be obtained at a moderate price, where materials suitable for the induction furnace could only be obtained at a prohibitive price. They are,

as regards quality, both able to make highest class carbon steels, but from a practical point of view, the resistance furnace is more adaptable as regards its raw material, and has the advantage of being very similar in general design to an ordinary Siemens furnace, so that so far as the metallurgical operations are concerned, repairs, etc., an ordinary steel smelter could in a very short time manage the furnace as easily as a gas-fired Siemens furnace.

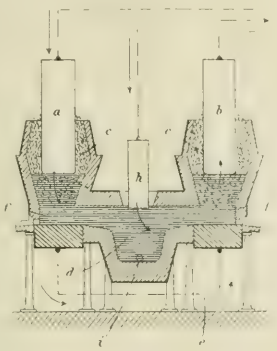


FIG. 1.—FOUR-HEARTH FURNACE.

"In the present stage of development, neither type of furnace can be regarded as a competitor to either the Siemens or the Bessemer processes for the production of rail and structural steel, and can only compete successfully in the production of high-class crucible steel or steels for ordnance and other special purposes made in the Siemens furnace. In cases where very large steel castings are required of crucible steel quality, several electric furnaces, working so that they could be tapped into a common receptacle, before pouring the steel into the mold, should give excellent results and be much more economical than the crucible process. Under favorable conditions, electric energy might compete with gas as regards cost, but until it is possible to use furnaces of from 30 to 40 tons capacity, the extra labor charges inseparable from small furnaces will prevent them from holding their own against the Siemens or Bessemer process."

The tensile tests of both the Kjellin and Héroult steels are all very satisfactory and are what one would expect from high-class steel containing different percentages of carbon; the maximum stress increases with the carbon to about 0.9 per cent, with a corresponding decrease in elongation and reduction of area. The steels were all heated to a temperature of 600° C., which is below the carbon change point, to remove any stress due to cold working. In the lower carbon steels the elastic limit is exceptionally high, the ratio of elastic limit to maximum stress being 70 per cent in No. 5 A, 82 per cent in No. 7 (658), and 70 per cent in No. 9 (559).

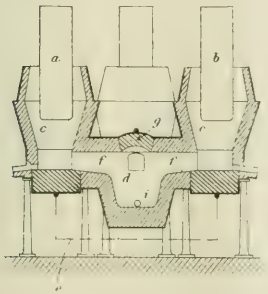


FIG. 2.—FOUR-HEARTH FURNACE.

Photomicrographs of the steels from the special experimental charges show that the structures were quite normal, except that in the low carbon steels the ferrite areas were exceptionally soft. They presented no special features, and, in fact, could not be distinguished from crucible steels.

REDUCTION OF PIG IRON FROM ORES.

A short test was made at La Praz in a Héroult furnace, commonly used for the manufacture of ferro-chrome and similar alloys. "This impromptu experiment has no bearing on the economic production of pig iron, and was simply arranged by Mr. Héroult to demonstrate to the commission how, even under most disadvantageous conditions, iron ore could be reduced with the electric furnace."

At Livet, the Commission saw direct smelting carried on continuously for some days, on a scale and under conditions which permitted one to form a general opinion as to the commercial possibilities of the process. These are the works of Messrs. Keller, Leleux and Co., and the furnace is designed by Mr. Keller. The furnaces are used sometimes for the direct reduction of iron ore, and sometimes for the production of ferro-silicon or ferro-chrome, according to the requirements of the firm at the particular time.

From the diagrammatic sketches (Figs. 1 to 3) in sectional plan and elevations, it will be seen that two or more ordinary furnaces with vertical electrodes are connected by a central well, and the current flows to and from each furnace through the vertical electrodes *a* and *b*. Preferably four hearths are connected, arranged so that the metal, as it is reduced, flows into the central well, from which it can be tapped into pig beds or a ladle to suit the particular requirements. "If four hearths (*cccc*) are used, they can be divided into two groups which are connected with each other in series, the two hearths forming each group being connected with each other in parallel. In such an arrangement the electric current will be broken during casting, when the well is emptied of its contents, and this would not only interfere with the working of the furnaces, but also with the working of the electric generators. To avoid this, the soles of the furnaces are made electrically conductive, and are connected with bars of copper (*e*), which connect hearths of opposite polarity in the manner shown in Fig. 1 to 3. As the flow of the current through the fused material decreases during casting, it flows through the soles of the hearths and conductors (*e*), and increases in direct ratio with the fall of the current in the fused mass connecting the hearths; and, finally, when the hearth is emptied, the entire current flows through the conductors (*e*).

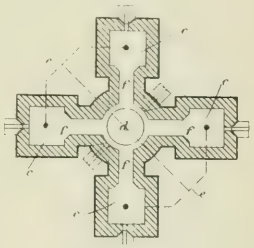


FIG. 3.—PLAN OF FOUR-HEARTH FURNACE.

"After casting the fused metal again collects in the crucible (*d*), and remakes the broken circuit, so that the current again begins to flow through the fused mass. These short-connections prevent any irregularity or great variation in the distribution of the current, and for this arrangement at least two furnaces are necessary. In the event of the metal becoming chilled in the central well, it can be heated by a subsidiary electrode (*h*) to the required temperature for casting."

The furnace in which the first experiment was conducted at Livet consisted of two hearths connected by a well. The waste gases were allowed to escape and burn at the top of the furnace, and no doubt a distinct economy would be effected if the furnaces were made deeper than those at Livet, so that a longer column of descending materials would be able to absorb more effectually the sensible heat of the gases. There was one experiment made in these furnaces, lasting fifty-five consecutive hours, and a second lasting forty-eight hours, in two furnaces similarly designed, but without the well.

The points to which special attention was given during the investigation were: First, the output of pig iron for given consumption of electric energy. Second, the yield of metal per ton of ore charged. Third, the quantity of coke required as a reducing agent. Fourth, the quality of pig iron obtained, with special reference to its suitability—(A) For steel manufacture. (1) Bessemer or Siemens acid process. (2) Bessemer or Siemens basic process. (B) Pig suitable for foundry purposes.

Mr. Harbord gives in detail the whole procedure of the two tests which were made. It is impossible to abstract these data briefly. The chief general result is that so far as the experiments go, they seem to show that the quality of the iron produced in the electric furnace depends upon maintaining the same conditions as in the blast furnace, the only difference being that one is using electrical energy instead of the direct combustion of carbon to produce the necessary temperature. Some important special results of these tests are summarized below in articles 3 to 9 of Mr. Harbord's conclusions. Concerning the cost of the process in comparison with that of the blast furnace, the following different items must be taken into account.

Electrical Energy.—The mean consumption in the two tests was 0.350 e. hp.-years per ton of pig iron. (See also above the figures in Mr. Brown's report.) With improved appliances and larger furnaces, this may be considerably reduced, but for the present it will be safer to take this figure as a basis for calculations. At $10.00 per e. hp.-year, this is equivalent to $3.50 per ton of pig.

Electrodes.—According to Mr. Keller, the cost of the electrodes, including the materials, labor, coking, etc., is about $45.00 per ton, and the consmuption is rather below thirty-four pounds per 2000 pounds of pig iron; this is equal to a cost of $0.77 per ton of pig iron produced.

Coke.—The coke required per 2000 pounds of pig iron is approximately 685 pounds. Taking coke at $7.00 the cost of the reducing agent is $2.38 per 2000 pounds of pig produced. In a modern blast furnace, working on a similar ore, the coke required is about 1850 pounds per 2000 pounds of pig iron, costing $6.40. [After the second experiment, a few charges were made in which the same ore mixture was used, except that the coke was replaced by charcoal. These charges, however, did not work very satisfactorily, as, owing to the ease with which the charcoal oxidized, a large portion burnt away on the top of the furnace, long before it got anywhere near the zone of reduction of the furnace. Mr. Keller is of the opinion that charcoal could be used provided it were first briquetted with the ore, and the briquette broken up to the size of one-inch cubes. Mr. Harbord agrees with him that probably charcoal could be used in this way, and in all probability, if thus intimately mixed with the ore, there would be comparatively little loss by oxidation on the top of the furnace, and the charcoal would do the work of reduction efficiently in the furnace.]

Fluxes.—Mr. Harbord thinks that the cost of lime per ton of iron will be about the same for the electric furnace as for the blast furnace.

Labor.—Mr. Keller estimates that a plant properly equipped for mechanical mixing and charging, producing 100 tons per twenty-four hours, would require sixty men. Mr. Harbord thinks that on starting, a larger number of men would be required, and that for the first year or so it is safer to assume eighty men.

Two estimates are given on the total cost of producing 2000 pounds of pig electrically, these two estimates being those of Mr. Keller and Mr. Harbord respectively. The differences in the two estimates are in the amount of lime and electrical energy required. Mr. Keller assumes 300 pounds of lime and 0.226 hp.-year, Mr. Harbord 400 pounds of lime and 0.350 hp.-year. The total cost without royalty, as estimated by Mr. Keller is $10.71; that of Mr. Harbord $12.05. Against this we have the cost in the blast furnace equal to $11.34. On the basis, therefore, of fuel at $7.00 and electrical energy at $10.00 per e. hp.-years, the cost of production in the electric furnace and in the blast furnace is almost the same.

Economical electric smelting is simply a question of the relative prices of fuel and of electric energy. With very high-price fuel, owing to the large amount required—nearly three times that of the electric furnace—the blast furnace is placed at a disadvantage; and, on the other hand, with fuel at anything below $7.00 per ton, the electric furnace cannot hold its own. It must be borne in mind that for blast furnace purposes, a hard, mechanically-strong coke must be employed, but for electric smelting, small anthracite, or other small coal or fine coke, provided it is fairly free from sulphur, could be used. Such small coal, anthracite or coke, could probably be obtained at half the price of coke suitable for blast furnaces, and in such cases the reducing agent for the electric furnace would make the cost per ton of pig $1.00 less. If anthracite collieries were anywhere near, large quantities of small anthracite might possibly be obtained at a very low figure. For the purpose of comparison, it has been necessary to consider the value of the fuel per ton as being the same in each case, but local conditions, such as a good supply of a cheap fuel which is useless for blast furnace work, but suitable for electric smelting, might so reduce the cost of production in the electric furnace as to enable it to compete successfully with the blast furnace. Provided charcoal could be obtained cheaply, it could probably be used if it were briquetted with the ore. Mr. Harbord then makes some brief remarks on electric pig iron smelting, in combination with steel making.

Conclusions of Mr. Harbord.

As the result of his investigations into the metallurgy of the electric production of steel and the electric smelting of pig iron, Mr. Harbord gives the following conclusions:

"1. Steel, equal in all respects to the best Sheffield crucible steel, can be produced either by the Kjellin or Héroult or Keller processes, at a cost considerably less than the cost of producing a high-class crucible steel.

"2. At present, structural steel, to compete with Siemens or Bessemer steel, cannot be economically produced in the electric furnaces and such furnaces can be used commercially for the production of only very high-class steel for special purposes.

"3. Speaking generally, the reactions in the electric smelting furnaces as regards the reduction and combination of iron with silicon, sulphur, phosphorus, and manganese, are similar to those taking place in the blast furnace. By altering the burden and regulating the temperature by varying the electric current, any grade of iron, grey or white, can be obtained, and the change from one grade to another is effected more rapidly than in the blast furnace.

"4. Grey pig iron, suitable in all respects for acid steel manufacture, either by Bessemer or Siemens processes, can be produced in the electric furnace.

"5. Grey pig iron, suitable for foundry purposes, can be readily produced.

"6. Pig iron, low in silicon and sulphur, suitable either for the basic Bessemer or the basic Siemens process, can be produced, provided that the ore mixture contains oxide of manganese, and that a basic slag is maintained by suitable additions of lime.

"7. It has not been experimentally demonstrated, but from general considerations there is every reason to believe that pig iron low in silicon and sulphur can be produced, even in the absence of manganese oxide in the iron mixture, provided a fluid and basic slag be maintained.

"8. Pig iron can be produced on a commercial scale, at a price to compete with the blast furnace, only when electric energy is very cheap and fuel very dear. On the basis taken in this report, with electric energy at $10.00 per e. hp.-year, and coke at $7.00 per ton, the cost of production is approximately the same as the cost of producing pig iron in a modern blast furnace.

"9. Under ordinary conditions, where blast furnaces are an established industry, electric smelting cannot compete; but in special cases, where ample water-power is available, and blast furnace coke is not readily obtainable, electric smelting may be commercially successful.

"It is impossible to define the exact conditions under which electric smelting can be successfully carried on. Each case must be considered independently, after a most careful investi-

gation into local conditions, and it is only when these are fully known that a definite opinion as to the commercial possibilities of any project can be given."

CONCLUSIONS OF DR. HAANEL.

With respect to the above conclusions of Mr. Harbord, Dr. Haanel makes the following remarks.

"Nothing requires to be added to Mr. Harbord's conclusions regarding the electric production of steel; in reference to the production of pig, however, it must be pointed out that

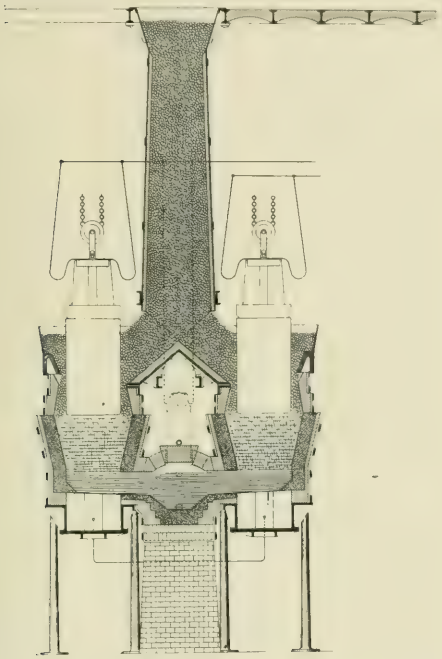


FIG. 4.—IMPROVED FURNACE FOR MELTING PIG IRON.

the results obtained at Livet were results of experiments in furnaces not specially designed for the production of pig from iron ore. With the improved furnace of which drawings are given in Fig. 4, permitting, on account of the higher column of charge, a more effective use of the heat of the resulting gases, and of the reducing power of the CO evolved, a much better figure than the one obtained would result.

"The modern blast furnace, and the different methods for the making of steel as at present employed, are the result of a hundred years of experience, and have reached their present perfection through many modifications, which, in many instances, were accepted and introduced into practice only after much hesitation and opposition. The process of the electric reduction of iron ore must yet be regarded as in the experimental stage; in fact, no plant exists at the present time where iron ore is commercially reduced to pig by the electric process. The more remarkable, therefore, it appears, and the more gratifying it is regarding the future of electric smelting, that experiments made off hand, so to say, in furances not at all designed to be used for the production of pig, should give a figure of cost which would enable the experimental plant employed to compete with a blast furnace in regions where electric energy can be had for $10.00 per e. hp.- year, and where coke is quoted at $7.00 per ton.

"I am credibly informed that the water power at Chats Falls can be developed at a cost to produce an e. hp.-year at the rate of $4.50. There are probably many water powers favorably situated as regards good bodies of ore in the provinces of Ontario and Quebec, which can be developed as cheaply. When such power is owned by the company intending to use it for electric smelting, and peat, coke or briquetted charcoal, made from mill refuse,* which would probably not cost more than $4.00 per ton, is employed for reduction, the cost of two of the heaviest items entering into the cost of producing pig by the electric process is reduced to on-half.

"When it is considered that the electric process is applicable also to the smelting of ores, such as copper, etc., and that the furnaces are of simple construction, the temperature available 1000° C. above that of the blast furnace, and the regulation of the heat supply under perfect control, it is reasonable to expect that the near future will witness great strides in the application of electric energy to the extraction of metal from its ores, and that familiarity with handling large currents and experience gained in electric smelting will result in solving the difficulties encountered in the smelting of ores, which up to the present time have proven refractory to all economical processes known."

MODIFIED FORM OF KELLER FURNACE FOR MELTING PIG IRON.

In the improved form of the Keller furnace, mentioned above in Dr. Haanel's conclusions and shown in Fig. 4, the interior of the furnace comprises several very distinct parts:

1. At the lower part, the crucible of the furnace in communication with the central crucible connecting the hearths.

2. The boshes of the furnace in the form of a truncated cone expanding towards the top—which constituted the zone of liquefaction of the slag, and of decantation of the metal and slag.

3. The body of the furnace, of an elongated and slightly conical shape, widening towards the base.

4. A hopper-of conical form widened towards the top. The upper part of the hearth, just below its junction with the boshes, constitutes the zone of the furnace where the maximum reducing action takes place.

The gas proceeding from the reduction rises in the body of the furnace so that the charge filling this part, already heated, more by caloric conduction than by radiation, from the intense heat at the center of the furnace, comes in contact with the hot gases, producing a partial reduction of the oxide of iron.

The body of the furnace ought, therefore, to be sufficiently high in order that the gases, traversing an adequate thickness of charge, may pass out from the mouth of the shaft, cooled and without pressure. In a final type of furnace Mr. Keller will provide the upper part of the furnace with gas collectors for the purpose of utilizing the escaping gases for the preliminary drying of the charge by making these gases pass in a state of combustion through the charges which carry the charge to the charging hopper.

For the type of furnace proposed for the installation of a plant of 100 tons capacity, the electrodes will be increased to 1.0 meter on the side and an auxiliary electrode will be provided for the central crucible, to be employed to heat the contents of it, in case for any cause there should prove to be danger of the metal setting. (This is already shown in Figs. 1 to 3, above.)

To ensure the continuity of the work, the renewing of the electrodes in the Keller furnace is effected in a few minutes by means of a very simple system of two carriages running on perpendicular rails, and each capable of being placed in the axis of the shaft.

When the replacing of an electrode becomes necessary, the new electrode all prepared and suspended by its own system of elevation, is hoisted on the charging floor of the furnace and brought near the corresponding shaft; the electrode to be removed is brought out and taken away by means of its rolling system. The new electrode is immediately put into the

* In the Ljungberg continuous kiln refuse wood is burnt into charcoal at 33 per cent less cost than in heaps, and with 22 per cent higher yield.

place of the old one. During this time, the source of energy does not undergo any variation on account of the method of distribution employed. In fact, the total intensity, half of which passes into each electrode of the same pole in the normal working of the furnace, passes now into the one electrode remaining alone on this pole during the time of the replacing of the second electrode. This increase of intensity during a few minutes cannot derange in any way the working of the apparatus.

The manipulation of the electrodes and the control of the electric action is effected from a single station on a working platform, where the operator has all the measuring apparatus under his eyes. The operation is so easy that a single man can readily superintend the regulating of a whole battery of furnaces.

Dr. Haanel states that the Commission has been able to observe that the measuring apparatus showed very steady current, and presented only very slight and progressive variations, not necessitating any special skill on the part of the person attending to the regulation.

* * * *

In the foregoing we have given as concise as possible a review of the first 116 pages of the volume which deals with the report on the European electric steel and iron processes. Then follows a brief report of a special Commission on the Ruthenburg process of electric smelting of magnetite. This Commission consisted of Dr. E. Haanel and Messrs. Higman and Locke. The Commission which visited the Ruthenburg experimental plant at Lockport in July, 1903, has reached the following conclusion. "From these results it is evident that the reduction of the magnetite, either in the reduction gap of the furnace, or in the soaking pit below the furnace, had been insignificant. Whatever the claims made by the patentee for his process, as exhibited to the Commission, the foregoing results of the investigation demonstrate its entire failure as a process for either agglomerating and fritting the finely-divided ore, or for any useful reduction of the iron ore. The fact that the magnetite loses its magnetism before incipient fusion takes place will prevent the agglomeration of the charge in the pit and the narrow gap between the poles, through which the charge requires to pass, will always render the capacity of the furnace small. These two facts preclude the hope that modifications of the process will render it commercially useful for agglomerating finely-divided ore, in substitution of briquetting."

As an appendix, fully illustrated translations of various valuable papers of French and Italian electrometallurgists are printed, this appendix covering the last 100 pages of the volume. The papers are the following: Henri Harmet on electrometallurgy of iron; G. Gin on the electric manufacture of steel; E. Stassano on his electrothermic process for the reduction of iron ore, and Ch. Vattier on the Keller process of treating copper ores in the electric furnace.

FARADAY SOCIETY MEETING.

The eighth ordinary meeting of the Faraday Society was held Tuesday, October 25, 1904, in the library of the Institution of Electrical Engineers, in London. Dr. F. Mollwo Perkin, treasurer, occupied the chair.

The Measurement of the Potential of the Electrodes in Stationary Liquids. The Determination of Changes of Concentration at the Cathode During Electrolysis.

Dr. Henry J. S. Sand read an abstract of his paper on the above subject and illustrated it by lantern views of his apparatus, and of the curves embodying the numerical results of his experiments.

With a view to determine electrode-potentials in solutions, the concentration of which in contact with the electrode should be known as accurately as possible, a method was elaborated for the measurement of potentials of electrodes in stationary liquids free from convection currents.

The apparatus employed was designed so as to allow the electrode to be placed accurately horizontally at the top or at the bottom, according as the electrolyte becomes lighter or heavier during electrolysis. The liquid connection to the normal electrode is tapped off about 3 to 4 mm. in front of the electrode, the resistance between the junction and the electrode being found either by calculation or else directly by means of a Wheatstone bridge arrangement for alternating currents, partly composed of condensers instead of resistances.

The method was checked by a series of experiments with a copper-sulphate solution, and gave satisfactory results for the diffusion coefficient of copper sulphate. The electrode-potential of a silver solution showed irregularities which are undergoing further investigation.

When two reactions take place, the method may show their successive occurrence by a sharp break in the potential-time curve, analogous to Nernst and Glaser's breaks ("Knickpunkte") in their potential-current curves; the conditions existing at the electrodes are, however, more definitely known than in the "Knickpunkt" method. An alcoholic solution of cuprous chloride which had become partially oxidized to cupric chloride showed such a break corresponding to the processes: reduction of cupric chloride and deposition of copper.

When acid solutions of nitrobenzene were electrolyzed the time-potential curves showed characteristic retrogressions of potential after a definite time, possibly corresponding to changes in the condition of the cathode.

From experiments on alkaline solutions of nitrobenzene a lower limit for the diffusion coefficient of nitrobenzene in the solutions experimented upon was calculated, and it was shown that Haber's results regarding the dependence of electrode-potential on current-density cannot be explained by concentration changes at the electrode. This result is of great interest in connection with the fundamental question whether electrode processes are of a reversible nature; that is, whether on the boundary between electrode and electrolyte, chemical equilibrium must be supposed to remain continually established.

The matter may also be stated in the following manner, corresponding to a form in which it has recently been put forward by Nernst as a general principle; differences of chemical potential cannot exist for a finite period of time on the boundary of two phases, that is "between infinitely near points," as this would lead to infinitely great forces and reaction velocities. According to this assumption the actual velocities of electrochemical reactions and all others which occur on the boundary of two phases, are infinitely great as soon as conditions of equilibrium have been overstepped by a finite amount, the observed velocities being simply limited by the rate with which diffusion and convention renew the material removed by the reaction. As conditions of equilibrium in electrochemical reactions are determined by the electrode-potential (*i. e.*, the drop of electromotive force on the boundary between electrode and electrolyte), and the rate of these reactions is proportional to the current strength, this may be expressed in the following manner: "When the electrode-potential at which a reaction begins has been exceeded by a finite amount, the current strength becomes independent of it, being only limited by the velocity of convection and diffusion."

Several experimental facts conform to this rule. However, the principle seems sufficiently invalidated for *a priori* application to actual cases owing to the impossibility of stating that the atoms chemically reacting on the boundary of two phases are in infinite proximity. In fact the results of sev-

eral recent researches, notably those of Haber stand in opposition to conclusions drown from the principle under discussion. The object of all these researches is the investigation of the dependence of electrode-potential as defined above on current-density. In Haber's work the reduction of nitrobenzene was examined, but instead of finding the current-density to be independent of the potential of the cathode, his results point to a logarithmic dependence of the latter on the former. In fact he has partially explained his results, starting from the not improbable assumption that the variations of potential are brought about by the absorption in varying concentrations of hydrogen, or other reducing material, by the electrode. In the further elaboration of this view his results may all be foretold, if we adopt as an empirical fact that the velocity of reduction at the electrode v depends on the concentration of hydrogen c in it according to the relation $v = kc^m$, in which k and m are constants depending on the conditions of the experiments.

In contradiction to this, Nernst's view would require that once the conditions of equilibrium have been everstepped, the above velocity should be infinitely great. As a matter of fact, Haber's results have been doubted by Brunner, who believes that changes of concentration in the liquid adjoining the electrode may be partly responsible for them. To this Haber and Russ have replied, stating reasons for the correctness of the results obtained by the former. Now, it is important that the present author arrives at the result that the variations of the electrode-potential with current-density observed by Haber cannot be explained as the result of concentration changes at the cathode.

In the discussion which followed, Dr. F. M. Perkin referred to the great practical importance of potential measurements; for example, in oxidation or reduction processes slight differences in the potential often mean very great differences in the amount of energy absorbed. Prof. Threlfall said that there was too much uncertainty, due to unknown changes, in complex phenomena such as had been investigated by the author, for the experiments to yield a definite and finite answer. More valuable results might be looked for at the present stage of knowledge if the simpler problems in electrolysis—familiar difficulties that occurred in one's daily practice—were attacked. As regards the experiments themselves, he thought that the method of employing a capillary tube in connection with the cathode for measuring electrode-potentials, would yield as accurate results as those obtained by the author. Dr. Sand, in reply, said the chief purpose of his work was to show the applicability and limits of his method, although he felt the force of what Prof. Threlfall had said. The capillary tube method was useless in experiments like these, which were really diffusion experiments, as he particularly wished to avoid convection currents.

A Suggested New Source of Aluminium.

Miss Buena Pool presented a paper in which she called attention to the work of Messrs. Holland and Warth, a fuller account of which may be found in the Geological Magazine for 1903.

While practically all the aluminium produced at the present day is made from bauxite, of which the British Isles possess but scanty deposits, the authoress pointed out that in India there is a vast treasure-house of aluminium in laterite deposits spread over the surface of thousands of square miles of country waiting for the spade of the prospector. The laterite deposits of India have long been a puzzle to geologists. They occur spread over vast areas as a purely superficial deposit of depths varying from a few feet to a few hundreds of feet, chiefly over the Deccan trap area of Central India. Until recently, laterite, in consequence of its appearance and consistency, was loosely classed as a clay; recent careful investigations and analyses seem to show, however, that it is much more closely analogous to bauxite, the aluminium being present in the hydrated form, and not as silicate.

Four distinct classes of laterites are described in detail. From specimen analyses which are quoted, it would appear that the high-level laterites in particular bear an obvious and striking resemblance to ordinary bauxite. The low-level laterites contain much free silica and clay. The conclusion of the paper is that these Indian bauxites have all the characteristics to render them commercially valuable; their pureness, ready accessibility, widespread occurrence at all elevations, and association with flowing water, pointing them out as an almost perfect source of aluminium.

Analyses of six specimens of high-level laterites follow; with the exception of two specimens with admixed quartz sand, they show very little silica.

	Marwara.	Makab.	Sartara.	Nilgiris.	Karad.	Satara.
H_2O	26.82	24.99	23.88	20.70	11.82	14.39
Quartz, SiO_2	....	....	....	...	1.77	....
SiO_2	3.90	.72	.37	3 14	4.23	.90
TiO_2	.38	.42	4 45	....	.10	1.59
CaO	.35	....	.86	....	.52	.64
MgO	....	....	....	....	trace.	.20
Fe_2O_3	13.75	23.41	26.71	37.88	51.25	56.01
Al_2O_3	54.80	50.46	43.83	38.28	30.86	26.27
	100.00	100.00	100.00	100.00	100.00	100.00
Molecules of Water from one Molecule of Aluminium.						
	2.80	2 83	3.11	3.09	2.19	3.13

The resemblance of these analyses to those of ordinary bauxite is obvious and striking. A general property of these high-level laterites is their infusibility before the blow-pipe. This serves to distinguish them from the low-level or detrital laterites.

In the discussion which followed Mr. W. Murray Morrison said that gibbsite ($Al_2O_3 + 3H_2O$, found at Kodikanal) could not be used as a direct source of aluminium, without being first treated for alumina. He did not think that the Indian laterites were likely to be used in England at present, as there is a plentiful supply of French bauxite to draw from, but, of course, they might, in time, be worked in situ. There was as yet no great demand for aluminium in India.

Electrolytic Oxidation of Hydrocarbons of the Benzene Series.—Part I. Hydrocarbons Containing the Methyl Group.

Dr. F. Mollwo Perkin gave a short account of a paper by himself and Mr. H. D. Law on the above subject. Owing to the more or less fragmentary style and the incompleteness of the literature dealing with the electrolytic oxidation of organic substances, the authors have commenced a detailed study of the electrolytic oxidation of hydrocarbons of the aromatic series.

They find that when an emulsion of toluene and dilute sulphuric acid or caustic alkali is electrolyzed the whole of the toluene is burnt up, but that when a mixture of acetone and toluene is electrolyzed in the anode compartment of a cell, benzaldehyde is produced. Unless, however, a large excess of acetone is present the yield of benzaldehyde is very small—even under the best conditions they were unable to obtain more than about eight per cent of benzaldehyde. The conditions employed were 550 to 600 cc. acetone, 50 grams toluene, and 250 cc. of dilute sulphuric acid. Beside benzaldehyde a small quantity of another product was produced which may be benzyl alcohol or a condensation product of the molecules of the toluene. They further oxidized ortho-meta- and para-xylene and mesitylene and pseudo-cumene under similar conditions. In each case the corresponding mono-aldehyde

was produced, with, on occasion, small quantities of the dialdehyde. Small quantities of a neutral product were also obtained, which are under examination. In no case was the corresponding acid produced. In the case of ortho- and para-xylene the yield of aldehyde was from 25 to 35 per cent. With the meta-xylene the yield was not above 10 per cent. Contrary to experience in ordinary chemical oxidations, the meta-xylene seems to show a greater tendency to be burnt up than the ortho- and para-xylenes.

With mesitylene and pseudo-cumene, the mono-aldehydes were also produced. With the latter substance, apparently a mixture of the three possible isomers. Further experiments are in progress, and the authors are also investigating hydrocarbons of the benezene series containing other groups than the methyl group and hydrocarbons containing mixed groups.

The interesting fact that the work of the authors has elucidated is that electrolytical oxidation, when carried out upon hydrocarbons of the benzene series, dissolved in an appropriate solvent, is not so energetic or so far-reaching as when these substances are oxidized with ordinary oxidizing agents, such as potassium permanganate and nitric or chromis acids. Now, in oxidizing hydrocarbons containing a methyl group, there are three possiblities. The first stage would result in the formation of an alcohol, the second in the formation of an aldehyde, and the third stage in the production of an acid. In hydrocarbons of the benzene series there is the further possibility of the benezene ring being split and the entire substance being burnt up.

With most chemical agents the oxidation proceeds directly to the third stage, and an acid results. By oxidation with chromyl chloride it is possible to produce the aldehydes, an addition product of the aldehyde being produced, which afterwards can be decomposed with water, when the aldehyde is produced, as, for example, with the xylenes, when we get—

$$3CH_3 \cdot C_6H_4CH(OCrCl_2 \cdot OH)_2 + 3H_2O = 3CH_3 \cdot C_6H_4 \cdot CHO + 2Cr_2O_3 + Cr_2(OH)_6 + 6HCl.$$

Ellis has shown that, when p-nitrotoluene is dissolved in acetic and sulphuric acids and subjected to electrolytic oxidation, nitrobenzyl alcohol is the main product. Renard and others have obtained small quantities of benzaldehyde by the electrolytic oxidation of toluene dissolved in alcohol. The authors have now carried this work further, and have shown that, when toluene, the xylenes and mesitylenes are dissolved in acetone and subjected to electrolytic oxidation, the main product produced is the mono-aldehyde. It is very interesting to note that, so long as there is any unchanged hydrocarbon present, the oxygen attacks it in preference to the aldehyde. In fact, the aldehydes, strange to say, do not appear to be readily oxidized by anodic oxygen.

Another fact to be noticed is that, with hydrocarbons containing more than one methyl group, only one group is attacked, and there appears very little tendency for the other group to be acted upon until the whole of the hydrocarbon has been converted into the mono-aldehyde.

The position of the group also seems to have a determining action; when the group is in the ortho- or para- position the yield of aldehyde is higher than when it is in the meta-position. It appears as if the hydrocarbon containing the group in the meta-position has more tendency to be completely burnt up than when the group is in either of the other positions.

In the case where there are three methyl groups present it appears that all the groups are more or less attacked, although only a mono-aldehyde is produced. With mesitylene, in which the groups are symmetrical, this did not lead to any difficulties. But in the case of pseudo-cumene, a mixture was obtained.

Although the chief product of oxidation is the mono-aldehyde, there is also a varying quantity of a neutral substance obtained, which may be the corresponding alcohol; but, as a portion of it boils at a very high temperature, the authors think it may be a condensation product, and that they may have obtained a styrol-like compound.

Mr. Frank Shedden, in a written communication, suggested the use of a gas-tight cell, and determining the amount of carbon dioxide given off to show the extent of any "burning" that might be taking place. He asked whether the authors had lowered the current density by increasing the anode surface. Dr. Perkin said that they had begun to make a study of the gases evolved. Their anodes were of platinum, so they had only used small ones. The chief difficulty they wished to overcome was the formation of tarry products owing to the concentration of H_2SO_4 in the anode chamber after a time. Neutralization or withdrawal of solution were both out of the question.

ELECTRIC FURNACE METHODS IN IRON AND STEEL MANUFACTURE IN COMPARISON WITH THE ORDINARY METALLURGICAL PROCESSES.

By Prof. B. Neumann, Ph. D.

Practically all the various methods and apparatus in which the electric current is used to produce iron from ores, or to change pig iron into steel, or to manufacture high percentage ferro-alloys, have been described in previous issues of Electrochemical Industry: these articles also contain some figures, given by the inventors, on the power consumed in their processes.

In a long paper[1] in *Stahl und Eisen* I have discussed the use of the electric furnace for iron and steel production and have investigated the applicability of the different methods with respect to the quality of the product, and with respect to the power consumption. I have studied especially the question what the prospects are in the main iron countries (United States, Germany and England) for these electric furnace processes in comparison with the ordinary metallurgical processes, such as the blast-furnace process, the Bessemer and Martin processes, the crucible-steel process, etc. The results which I have reached should, I think, be of interest also to the readers of this journal.

The different electric furnace processes may be classified in two groups: First, those which produce only pig iron and alloys; second, those which change pig iron into steel; but this classification cannot be sharply made since Stassano[2] and Conley[3] use apparatus in which the reduction to pig iron and the refining process are simultaneously carried out. Keller,[4]

Process	Stassano		Heroult		Kjellin		Ferro-selicon
	A	B	C	D	E	F	G
Number of samples	5	2	2	1	8	3	3
Mn	0.068—0.272	0.09 —0 092	0.092—0.138	0.000	0.13 —0 54	0.33 —0.49	0 16—086
Si	0.018—0.048	trace	0.020—0.023	0.007	9.03 —0.85	0.35 —0.42	25.0 — 25.0
S	0.046—0.130	0.05 —0.059	0.016 —0.022	0.008	0.005—0 03	0.01 —0.015	0.01— 0 04
P	0.005—0 060	0.009—0.029	0.006—0.011	0.003	0.009—0.014	0 011—0.014	0.04— 0 12
C	0.084— 0.120	0.090—0.17	0.840—1.080	0.008	0.08 —1.70	0.95 —1.45	0.23— 0.48

[1] Stahl und Eisen. 1894. pp. 682, 761, 821, 883, 947.
[2] Electrochemical Industry, v. I., pp. 247, 461.
[3] Electrochemical Industry, v. I., p. 427.
[4] Electrochemical Industry, v. I., pp. 162, 421.

Héroult[5] and Harmet[6] use different apparatus for these two processes; while Kjellin,[7] Gin[8] and Girod[9] only refine the metal. The process of Ruthenburg[10] is not a real melting process, but is rather a briquetting method by which sintered, half-reduced products are obtained. Of the apparatus used for these purposes, those of Stassano, Keller, Héroult, Harmet and Conley employ carbon electrodes, while those of Kjellin, Schneider, Gin and Girod do not use carbon electrodes. Concerning the details of the furnace construction the reader may be referred to their description in previous issues.

In order to arrive at a proper estimate of the value of a technical process, the quality of the products is of great importance. It is to be regretted that with respect to this point not sufficient data are at the disposal of the writer for most processes. Some of them are not yet used on a large scale, while in other cases the inventors have not placed samples of their products at the disposal of the writer.

Concerning the chemical constitution of the products the table on page 488 gives some figures.

The following remarks may be made on the figures in this table; A are figures from the committee-report of Lucchini; B are figures of Goldschmidt; C are figures of analyses of tool steels; D of soft steel, the figures being given by the inventor; E gives figures of Gysinge steel from a paper of Benedicks; F figures of Stead; G are analyses of commercial products. Concerning products of Keller, the author has not data.

As to the physical properties of these products of the electric furnace, little is known. According to Lucchini, Stassano-metal contains too much sulphur to be forged when hot. On the other hand, Goldschmidt calls it a product similar to Martin steel. The writer has no data on the tensile strength of the steel made by Stassano and Héroult. Bertolus states that Keller steel may be compared with Martin and Bessemer steel. A forged and tempered sample gave 83.4 kg. per square millimeter tensile strength with 13 per cent elongation.

Very detailed tests of the mechanical properties of Gysinge steel have been made by A. Wahlberg.[11] With non-tempered samples of 0.7 to 1.2 per cent carbon, the tensile strength was 87 to 118 kg. per square millimeter, with 11.6 to 4.3 per cent elongation. With tempered samples of 0.7 to 1.2 per cent carbon the tensile strength was 73 to 85.4 kg. per square millimeter, with 14.6 to 11.1 per cent elongation.

With respect to homogeneity of structure the castings were equivalent to the best Swedish steels. The same may be said of the tensile strength and bending strength in comparison with Oesterby crucible steel. The resistance against concussion is even greater for electric steel.

The high-percentage ferro-alloys made in the electric furnace are superior to those made in the blast furnace, on account of greater purity and lower content of carbon. Moreover, the electric furnace enables the manufacture of higher-percentage alloys than the blast furnace; this is true as well for ferro-silicon, as for ferro-tungsten, ferro-titanium, ferro-chromium, etc.

In the ordinary metallurgical processes for reducing iron from ores, and for changing pig iron into steel, the energy required for the different reactions and physical changes is generally obtained by burning carbon (an exception being the Bessemer process). On the other hand, the electric furnace process tries to utilize electricity instead of carbon for heat production. Since electric energy is a very expensive form of energy, the power consumption of the processes and the heat efficiency of the apparatus, together with the price of electrical energy, are of decisive importance for the economical application of the processes.

To reduce one metric ton (1000 kg.) of iron from pure Fe_2O_3, 357.8 kg. of carbon are required; while 317 kg. are required for reduction from Fe_3O_4. The reduction from oxide consumes theoretically 1,213,139 calories, which can be replaced by 1403 kw.-hours. For the reduction from ores it is to be considered, however, that besides the reduction of iron to the metallic state, heat is consumed for the reduction of impurities, for heating the additions, for melting the slag, for heating the iron bath, for making up the losses due to radiation, and for the heat escaping with carbon oxide. If one calculates for an example of ore thermochemically the quantity of heat required, the result is about 2000 kw.-hours.

Now the question comes up what is the efficiency of the electric furnace and what are the other losses during operation on an industrial scale? Goldschmidt calculates an efficiency of 61 per cent for the Stassano furnace, while J. W. Richards found that electric furnace processes, in which the charge is heated with fusion and with chemical reactions, have an efficiency of 60 to 75 per cent. To reduce pig iron from the ores on an industrial scale, one would therefore have to expect a consumption of about 3000 kw-hours per ton of metal. This figure agrees approximately with the following experimental results and calculations.

Stassano consumes 3155 kw.-hours per 1000 kg. of metal with the use of pure hematite; Rossi 3354 kw.-hours with titanifernous ores; Keller gives the figure 2800 kw.-hours; Sjoestedt, when working on a small scale with roasted pyrrhotite, used 3100 to 3500 kw.-hours; Harmet calculates about 2600 kw.-hours, but he gives too low a figure for the loss by radiation; if his figure is properly corrected, one gets 3270 kw.-hours. An average value of 3000 kw.-hours, as assumed above, is therefore certainly not too high.

For the manufacture of ferro-silicon 5000 kw.-hours (Gin) and 3500 kw.-hours (Keller) are stated to be required. This large difference may, perhaps, be explained by differences in the constitution of the charge.[12]

For changing pig iron into steel, nearly all electrical processes employ a method similar to the ordinary open-hearth process. The amount of carbon contained in the pig iron is reduced by addition of wrought iron or scrap steel, and is often still further reduced by adding some iron ore. In this method, therefore, the electrical energy supplied to the furnace is to furnish only the heat required for melting the charge and for maintaining the temperature necessary for the refining process. The thermochemical calculation gives 378,360 calories or 438 kw.-hours, when starting with molten pig iron, and 753,560 calories or 871 kw.-hours when starting with cold pig iron.

For the operation on the industrial scale the following figures are given. When starting with molten iron, the number of kw.-hours required is 620, according to Harmet, 694 according to Keller, 600 according to Gin. When starting with the cold charge, the number of kw.-hours is 920 according to Conley, 882 according to Héroult, 966 according to Kjellin. Héroult's figure is very low, but it may be that the conditions are here different on account of the preliminary treatment of the metal bath. The average of real energy consumed is 900 to 950 kw.-hours per ton of steel.

The figures of the cost of operation given by the inventors do not permit a fair comparison for the reason that the cost of materials and the cost of power vary from place to place.

If the problem is to find for a certain district the cost of the electric process, and to compare it with the cost of the present metallurgical process, one has to consider that ore, additions and reducing material are the same for both processes with respect to their nature and quantity. The difference consists in the fact that the heat produced by carbon or coke is replaced by electrically generated heat. If we further assume that the cost of repairs and the wages of attendants are the same in both cases, the question is reduced to a com-

[5] ELECTROCHEMICAL INDUSTRY, v. I., pp. 64, 449, 287, 467
[6] ELECTROCHEMICAL INDUSTRY, v. I., pp. 422, 589.
[7] ELECTROCHEMICAL INDUSTRY, v. I., pp. 141, 377, 577.
[8] ELECTROCHEMICAL INDUSTRY, v. II., p. 20.
[9] ELECTROCHEMICAL INDUSTRY, v. II., p. 369.
[10] ELECTROCHEMICAL INDUSTRY, v. I., pp. 84, 202, 483.
[11] Jer. Annal., 1902, p. 296; Stahl und Eisen, 1904, p. 824.

[12] Concerning this point, see the article of Dr. G. P. Scholl, page 396 of our October issue.—Ed.

parison of the cost of a certain quantity of coke with that of the electrical energy equivalent to it.

The prices are as follows: Coke in the United States (Connellsville) $4.00, England $4.00, Germany $3.75, France (Livet) $8.00, Chili $20.00, Brazil $12.00. The cost of power in the United States (from water-power, at Niagara Falls) is, according to J. W. Richards, $20.00 per hp.-year, or $27.20 per kw.-year, or 32 cents per kw.-hour. If the cost is $15.00 per hp.-year, it is $20.40 per kw.-year, or 24 cents per kw.-hour. In Germany electrical energy, produced from blast furnace gases or from water power, is $20.00 per hp.-year. In the Alps electrical energy, developed from water power, costs $7.50 to $10.00 per hp.-year; in Chili $6.00, according to Keller.

Let us assume, for instance, a hematite ore, then there are required for reduction 413 kg. of carbon, for heating 566 kg., the latter quantity corresponding to 662.3 kg. of commercial coke, in the value of $2.65. On the other hand, for producing the same quantity of heat electrically by the processes so far proposed, there are at least required 2688 kw.-hours, which cost $6.45 to $8.60. To this is to be added $2.50 to $3.50 for consumption of electrodes. The electrical production of pig iron would, therefore, cost in the United States $6.50 to $9.00 more than the ordinary metallurgical process. The situation is exactly the same in Germany and England, even if other ores are used, but the calculation comes out quite differently if based on the conditions in Chili or Brazil. There the coke would cost $12.00 and $7.50, respectively, the electrical energy $1.75 and $1.50. Of course, there is to be added $5.00 or $6.00 for electrodes and $7.70 or $4.60, respectively for coke for reduction (against $1.60 in the United States). Anyhow, this example shows that the electric reduction of pig iron from ores may be possible in countries where fuel is scarce and waterpowers plentiful, while it is commercially impossible in the main iron countries.

In steel manufacture the charge and additions are also the same for both cases. The open hearth furnace produces one ton of steel with 220 to 250 kg of carbon, the electric furnace with 950 kw.-hours. There is, therefore, a cost of 55 cents to 60 cents for carbon, against $3.00 for electrical energy. The open-hearth furnace is, therefore, cheaper by about $2.50 per ton in the United States than the electrical furnace.

Kjellin and Benedicks, in Gysinge, have made in the electric furnace a fine crucible steel in the value of $42.90. They started with fine raw materials, the cost of the charge being alone $32.50. It is not probable that the fine material for the charge may be had cheaper at other places, while the cost of power at Gysinge corresponds approximately to that in United States and Germany. For these countries we may, therefore, assume the same cost of operation is in Gysinge. With the present crucible steel process there are required 35 to 40 crucibles per ton of product, and these crucibles stand only 3 to 5 heats, while 1200 kg. of carbon are used per ton. The cost of melting and the cost of crucibles is therefore about $12.00 to $17.00. With the Gysinge furnace, one ton of steel can be obtained in one single operation. The cost for brick work and repairs is $2.08, the cost of power $5.00, so that in this case the electric process is essentially more economical than the old crucible process. For refining steel the electrical process can, therefore, compete with the old crucible steel process in the main iron countries.

To sum up, we should expect that in the United States the blast furnace will continue to be used for reducing pig iron from ores, the open-hearth furnace and the Bessemer converter for making the ordinary steels, while only for making special steels and high-percent ferro-alloys the electric furnace can be used economically.

Technische Hochschule,
Darmstadt, Germany.

The production of iron ore in the United States was 35,019,308 long tons in 1903.

MATERIALS FOR RESISTORS.

By Francis A. J. FitzGerald.

The word "resistance" in its application to electricity has two meanings: (1) It connotes a property of a substance, and is used either in a qualitative or quantitative sense; (2) it is applied to the resistant substance itself. In writing the following article it was sometimes found necessary to resort to various circumlocutions for the purpose of avoiding such clumsy expressions as "the resistance of the resistance," and sometimes the reader was called upon to use an unnecessary mental effort to discover whether the word "resistance" meant the property of a substance or the substance itself. It therefore seemed advisable to use the word "resistor" to connote a substance used because of its property of offering resistance to the passage of an electric current, and to reserve the word "resistance" for the property either in a qualitative or quantitative sense.

So far as the heating of the charge in furnaces by resistance is concerned, the most elementary form is that in which the charge itself forms the resistor. Examples of this type are found in Acheson's graphite furnaces and Gin's steel furnace.

In theory, at least, the latter is the more simple, for the resistor consists of molten iron at an initial temperature of 1300° C. This is fed into a long canal, and is raised to maximum temperature of about 1900° C., and is eventually poured at a temperature of 1600° C. The total change of temperature in the resistor amounts, therefore, to 600° C., and apparently this does not produce any marked effect on the resistivity of the iron, since nothing is said about it in the published descriptions of the Gin process.

The conditions became more complex in Acheson's graphite furnaces. In these furnaces the resistor is composed of a mass of cold carbon which is raised to the highest attainable temperature, and there is thus produced a great change in resistance. In addition to the change in resistance caused by the increase in temperature there is a further diminution of resistance brought about by the conversion of the amorphous carbon into graphite. This is illustrated by the curve in Fig. 1, where the ordinates are the ratio of the electromotive force E to the current I and abscissæ are the time. It will be observed that after the lapse of a certain time $\frac{E}{I}$ becomes constant, that is, there is no further change in the resistance, and consequently the conversion of the carbon to graphite is complete. A curious characteristic of the curve is the increase of resistance near the beginning. A possible explanation of this will be discussed later.

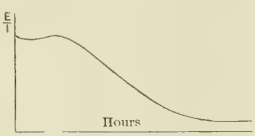


FIG. 1.—CHANGE OF RESISTANCE OF GRAPHITE FURNACE.

If it is assumed that the ratio of the resistivity of carbon at ordinary temperatures to that of carbon at the temperature of the graphite furnace is 2; that the ratio of the resistivity of amorphous carbon to graphite is 4, and, finally, that the change of resistivity produced in graphite by heating to any temperature is proportional to the change produced in amorphous carbon by the same means, then the ratio of the initial to the final resistance of the resistor in the graphite furnace is 8. In some cases this probably approximates actual conditions, but, as will be shown later, various factors enter into the determination of the resistance of a carbon resistor.

In order to work economically with an electric furnace it is usually important that the maximum power available be used throughout the furnace run, and if the resistor changes its resistance it is necessary to provide some means of regulating the voltage. In any furnace of this type let the initial

resistance of the resistor be R_1, the final resistance R_2, W the watts required for heating the furnace, E_1 the maximum voltage, and E_2 the minimum voltage required, so that W watts are used throughout the run. Then,

$$\frac{E_1^2}{W} = R_1 \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$\frac{E_2^2}{W} = R_2 \quad . \quad . \quad . \quad . \quad . \quad (2)$$

dividing (1) by (2)

$$\frac{E_1^2}{E_2^2} = \frac{R_1}{R_2}$$

whence $\frac{E_1}{E_2} = \sqrt{\frac{R_1}{R_2}}$ . . . . . (3)

Equation (3) therefore shows that in order to use the full available power throughout the run, the maximum and minimum voltages attainable must have to each other the ratio of the square roots of the maximum and minimum resistances of the resistor.

In furnaces like those used by Héroult, Keller, etc., for the manufacture of steel, where the resistor consists of a molten slag into which the terminals dip the regulation of the power used is effected by the depth to which the terminals are immersed in the slag. In such furnaces, however, relatively low temperatures are used. In furnaces where high temperatures are required, the resistor is usually composed of carbon, so that an exhaustive examination of that substance in this connection is desirable.

It must first be observed that the resistivity of carbon is reduced by about 50 per cent when it is heated to a high temperature. Assuming, therefore, that no other change is produced and that the resistor in a furnace is composed of carbon, then, if it is desired to use the furnace at its full power capacity throughout the run, it follows from equation (3) that the ratio of the maximum and minimum voltages required is given by

$$\frac{E_1}{E_2} = \sqrt{2}$$
$$= 1.41$$

If, however, the temperature of the resistor is higher than the carbon composing it has ever been at before, another factor enters in. The physical state of carbon is permanently changed by heat. Thus, when carbon is raised to a higher temperature than it has ever reached before, its density is increased; its heat conductivity is increased; its electrical resistivity is decreased; its resistance to oxidation is increased; its resistance to disintegration in certain solutions is increased. The change that concerns us at present is the decrease in electrical resistivity.

An experiment designed to illustrate this phenomenon was made by heating one end of a carbon rod to the highest attainable temperature in an electric furnace, while the other end remained at the temperature of the room. The intermediate part of the rod was covered with a heat insulator, so that there was a gradual fall of temperature along the rod. After heating as described, the rod was divided into sections by a number of lines drawn 1 centimeter apart and connected in series with an ammeter in a circuit giving a constant e. m. f. The drop of voltage along the sections was then measured by means of a millivoltmeter. As the resistance of the latter was rather low it was difficult to avoid errors due to making poor contact between the leads from the voltmeter and the rod. Five observations of the voltage drop along each section were made and the average and percentage average deviation calculated. The maximum percentage average deviation was 1.6, and the mean of the percentage average deviations was 0.67. The total variation of the current during the experiment was 1.1 per cent, and was an increase due to the heating of the rod and consequent lowering of its resistance. The results obtained, therefore, are not accurate but sufficiently satisfactory to give an approximate idea of the change in resistivity produced by heat.

From the observations the conductances of the different sections of the rod were calculated and the results plotted so as to give the curve shown in Fig. 2, where the abscissæ are distances in centimeters from the cool end of the rod, and the ordinates are conductances.

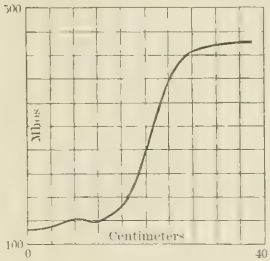


FIG. 2.—CHANGE OF CONDUCTIVITY ALONG CARBON ROD.

The curve is somewhat misleading, for it might appear at first sight that at first the change in conductivity was gradual with increased temperature, and afterward was rapid. This conclusion would be erroneous, for the abscissæ are distances from the cool end of the rod, and equal increases in distance do do not necessarily mean equal increments in temperature. As the end of the rod in the interior of the furnace is raised in temperature the physical properties of the carbon are changed, as already described, therefore the heat conductivity of that part of the rod is greater than that of parts near the cool end. Hence the fall of temperature along the hotter parts of the rod is more gradual than along the parts further removed from the hot end. Moreover, there are other changes going on in the rod which must affect the temperature gradient. At one part silica is reduced and silicon carbide formed, at another various substances are vaporizing or condensing, and so forth.

The practical conclusion to be drawn from this phenomenon of the permanent change of resistivity produced in carbon by high temperature is that before using it as a resistor it should be raised to the maximum temperature to which it will be submitted in practice. Of course, this is not absolutely necessary, for in any furnace where a certain temperature is required in the resistor, the carbon may be raised to that temperature the first time the furnace is run. Nevertheless, in most cases it will be advantageous to make the resistor of carbon that has already been heated to as high or a higher temperature than that required.

The best plan is to use graphitized carbon for that form of carbon may be described as stable in its physical characteristics, so that the only change that is experienced when using it as a resistor is temporary and due to the increase in temperature.

In addition to the physical change occurring in carbon when heated to a high temperature, there are chemical changes if, as usually is the case, there are impurities present. Referring again to the conductance curve of Fig. 2, it will be observed that at a point about 10 centimeters from the cool end of the rod there is a decrease in the conductivity. Examination of the ash of the carbon at this point showed that amorphous silicon carbide was formed, and that might easily explain the decrease in conductivity. This would also account for the very gradual increase in the conductivity towards the cool end of the rod.

Such an explanation seems to be confirmed by the determinations of the densities of the carbon composing the sections of this part of the rod, for these show a rapid increase.

A similar explanation is offered for the increase in resistance observed in the resistance curve of the graphite furnace (Fig. 1).

In view of this effect it seems advisable to use pure carbon in the construction of resistors where the temperature at which they are used is high enough to cause the formation of carbides.

The next thing to be considered is the kind of carbon to be used as a resistor. It has already been shown that the carbon used should be in the form of graphite; but the properties of carbons that have been raised to the graphitizing temperature vary greatly, according to the kind of amorphous carbon used. For example, the different properties of carbon rods made from petroleum coke and lamp black have been described elsewhere:

"Two carbon electrodes were placed side by side in the electric furnace. One of these electrodes was made of the purest lamp black carbon, the other of petroleum coke, with the addition of about 2 per cent of ferric oxide. After removal from the furnace the electrodes were compared, with the following results:

Lamp Black Electrode.	Petroleum Coke Electrode.
Does not show any of the ordinary evidences of graphitization. The color of the carbon is unchanged, and it is still hard and brittle when an attempt is made to cut it with a knife. It will scarcely mark paper and will not take a brilliant polish when rubbed.	Has brilliant graphitic appearance. Can be readily cut with a knife. Takes a brilliant polish when rubbed. Marks paper like a pencil.
Density 2.05.	Density 2.20.
When used as anode in electrolyzing a solution of sulphuric acid the disintegration is very rapid.	When used as anode in electrolyzing a solution of sulphuric acid the disintegration is much slower than in the case of the lamp black electrode.
Burns with comparative ease when heated to bright redness in the air. In quantitative test it was found that the rate of oxidation was nearly 100 per cent greater than that of the petroleum coke electrode.	Burns with difficulty when heated to bright redness in the air.
Treated with the oxidizing mixture of potassium chlorate and nitric acid the specimen was converted into graphitic oxide.	Treated with the oxidizing mixture of potassium chlorate and nitric acid the specimen was converted into graphitic oxide.

"Applying Berthelot's definition, both of the specimens are graphite; but it will be observed that they differ in every respect, save in the one property of forming graphitic oxide."[1]

This shows very plainly that even when carbon is raised to the graphitizing temperature its properties will depend largely on the kind of amorphous carbon used, and that by choosing different kinds of carbon we may get variations in resistivity which are useful in the construction of resistors. As an extreme example, it is obvious that the resistivity of petroleum coke and retort carbon will be very different, even after heating both of them to the temperature of the graphitizing furnace.

Usually a solid carbon rod is not a satisfactory resistor, particularly if working on a large scale, since to generate energy at a sufficiently rapid rate to obtain a high temperature it is necessary to use a current of great amperage and low e. m. f. But if the carbon is broken up into many pieces the resistance of the mass is greatly increased, because of the number of points of contact which have a high resistance. It is evident that if the number of points of contact is increased the resistance of the resistor will be increased, other things being equal. This brings us to the discussion of granular carbon as a material for the construction of resistors.

If a mass of granular carbon is placed loosely in a trough, the ends of which are formed of carbon blocks connected with a source of current, a number of minute arcs are formed at the points of contact of the grains of carbon, and the whole mass soon becomes hot if the rate of development of energy in the circuit is sufficiently high. If, instead of putting the granular carbon loosely in the trough, it is pressed down so as to make fairly good contact between the grains, no arcs are formed, but close observation shows that the main generation of heat occurs at the points of contact of the grains.

If an ammeter is included in the resistor circuit and the e. m. f. is kept constant throughout the experiment, it will be found that the current increases, showing a decrease in the resistance of the resistor, as the temperature rises, till finally a point is reached where the resistance becomes constant. If the trough is now covered with a piece of asbestos board, so as to diminish the radiation of heat from the resistor, the current will again gradually increase. For, by lessening the radiation of heat the temperature of the resistor is increased and the resistance diminished.

Instead of covering the resistor with a piece of asbestos board, let a weight be laid in it. The moment this is done the ammeter rises, indicating an immediate reduction in the resistance. This is caused by the reduced resistance of the points of contact of the grains of carbon.

To illustrate some of the characteristics of granular carbon resistors, the following experiment was made. In Fig. 3 the granular carbon resistor is shown in plan. W, W are the five brick walls of a trough, the ends of which are formed of the carbon terminals T, and T_2. The trough is divided into two parts by the carbon plate M. Granular coke that had been previously graphitized was then introduced into each half of the trough to a depth of 10 cms. The granular coke G1 was composed of grains that passed through a screen having 5 meshes to the linear inch, and were held in a screen of 6 meshes to the inch. G2 passed through a 3-mesh screen and was held in a 4-mesh screen. Good contact between the terminals and the granular coke was made by tightly packed graphite powder P1 and P2. Carbon rods A, B, C and D were plunged in the granular carbon. Wires were attached to these rods so that they could be connected with a voltmeter and the voltage between A and B or C and D determined. Voltage between T1 and T2 was 110 volts. The current passing at any time was determined by an ammeter in series with the resistor.

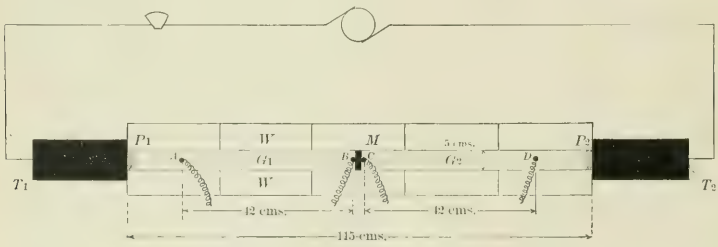


FIG. 3.—TEST OF GRANULAR CARBON RESISTORS.

[1] Monographien über angewandte Elektrochemie XV. Band. "Künstlicher Graphit," von J. A. J. FitzGerald.

After the current was thrown on, readings were taken at frequent intervals of the ammeter and the voltmeter connected up alternately with A-B and C-D. In a well-conducted experiment there should be two voltmeters used, so that the readings might be taken simultaneously; but, unfortunately, in the present instance only one voltmeter was available. The time between readings of the voltage between A and B, and C and D was about 30 seconds. After an interval of some minutes G1 was covered with a piece of asbestos board, so as to diminish the radiation of heat from that part of the resistor. Later a weight of 3.5 kilograms was placed on G1, then on G2 and finally the same weights on both parts of the resistor. The area of a weight resting on the resistor was 67.5 square centimeters, thus giving a pressure of about 52 grams per square centimeter. The results obtained are given in the following table:

Time Mins.	Volts G1.	Volts G2.	Amperes.	Remarks.
0	50.0	39 5	...	
2	46.5	37 0	70	
3	46.5	37.5	75	
4	46.0	37.0	85	
7.5	46.0	36.0	95	G1 bright red heat, G2 dull red heat
14	48.0	35.0	90	
16	48 0	34.5	90	
18.5	48.0	34 5	85	33 cms. of G1 covered with asbestos
20	47.5	36.0	85	
25	46.5	36.0	80	
29	46.0	37.0	80	
35	45.5	37.0	80	Asbestos taken off G1
39	45.5	37 0	80	
50	46.0	38.0	80	
52	34 0	45 0	105	Weight put on G1
53	40.0	42.0	100	Weight taken off G1
54	40 0	41.5	100	
55	46.0	28 0	120	Weight put on G2
56	43.5	34.0	112	Weight taken off G2
59	43 5	34.0	112	
60	42 0	30.0	135	Weights put on G1 and G2
63	44 0	3 0 0	138	
66	45.5	29 0	130	
68	45.0	32 0	100	Both weights taken off
88	46.0	32.0	100	

To facilitate the analysis of the results obtained from the experiment the curves in Figs. 4 and 5 have been drawn. The curve in Fig. 4 is drawn with minutes as abscissa and the

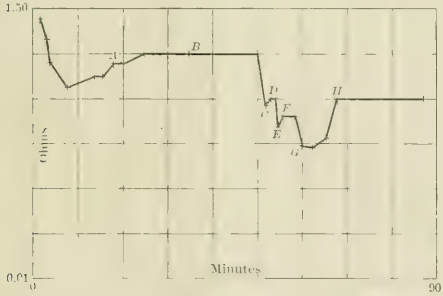


FIG. 4.—CHANGES IN RESISTANCE OF THE RESISTOR AS A WHOLE.

reciprocals of the current values as ordinates. Since the voltage at the terminals of the resistor was constant, the curve represents the changes in resistance of the resistor as a whole. The abscissæ of the curves in Fig. 5 are minutes, and the ordinates of the curves were obtained by taking the sum of the voltages between A and B, and C and D, and expressing them as percentages. The continuous line corresponds to G1 and the broken line to G2. These curves therefore serve to illustrate the relative resistances of G1 and G2 at any time during the experiment. All the curves have been lettered in the same way: At A the asbestos board was put in G1; at B the asbestos was taken off; at C the weight was put on G1; at D the weight was taken off; at E the weight was put on G2; at F the weight was taken off; at G weights were put on G1 and G2; at H the weights were taken off.

Consider first the curve in Fig. 4. As might be expected, the resistance decreases rapidly at first, since the resistivity of carbon decreases with increase of temperature. But at the end of 7½ minutes there is an increase of the resistance in spite of continued increase in the temperature of the resistor. As in the case of the resistance curve of the graphite furnace and the resistivity curve of the carbon rod, the most probable explanation of this increase in resistance is that the temperature of the points of contact of the carbon grains is sufficiently high to form carbides at the points of contact, and consequently to increase the resistance of the resistor. This explanation is

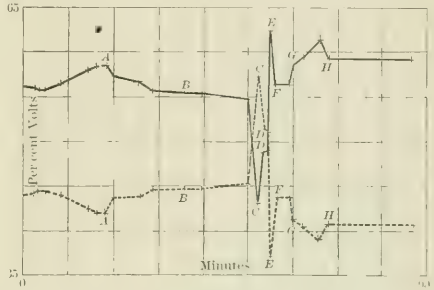


FIG. 5.—CHANGE OF RELATIVE RESISTANCES OF G1 AND G2.

confirmed by the observation that when using impure carbon grains in the resistor this phenomenon is much more marked than with pure carbon. In working a carborundum furnace with a resistor in the shape of a core of ordinary granular coke, the phenomenon is very distinct, the resistance first diminishing rapidly, then increasing, and finally diminishing again. On the other hand, if the core is composed of granular coke, which has been used in a previous run, and is therefore relatively pure, the phenomenon is much less distinct. The effect of putting the asbestos board over the resistor seems to be slight, the resistance apparently becoming constant. This result, however, is due to lack of sensitiveness in the ammeter. Other experiments of a similar kind have clearly shown that if the radiation of heat from a resistor is diminished there is marked decrease in resistance. The effect will be evident when the curves in Fig. 5 are examined.

A considerable decrease in resistance is obtained when the weight is put on G1 at C, followed by an increase of resistance at D, when the weight is removed. But it will be observed that placing the weight on G1 has permanently lowered the resistance. A similar result is obtained when the weight is put on G2.

Finally, the resistance decreases at G when weights are placed on both sections of the resistor. But shortly afterward the resistance begins to increase rapidly, the reason for this probably being the same as before, viz., the formation of carbides at the points of contact of the grains. At this stage of the experiment the resistor was becoming very hot, and the formation of carbides would therefore be rapid. Here it may be noted that when the experiment was over and the resistor had cooled, it was found that a large number of the grains of carbon were coated with a greenish substance which evidently was amorphous silicon carbide. This was very clear in the case of the grains composing G1, which was at a much higher temperature than G2.

Turning, now, to the curves in Fig. 5, it is observed that G1, composed of the smaller grains of carbon, has a greater re-

sistance than G2. It follows therefore that the generation of heat in G1 is more rapid than in G2, and this causing a more rapid increase in temperature, the resistance of G1 diminishes more rapidly than G2. At the end of 4 minutes, however, this condition is reversed, the resistance of G1 increasing as compared with G2, although the resistance of the resistor, as a whole, is still diminishing, as may be seen by referring to Fig. 4. But the generation of heat being much more rapid in G1 than in G2, the temperature of the former is now much higher and probably the formation of carbides has begun. In the table of observations it is noted at the end of 7½ minutes that G1 is at a bright red heat, while G2 is merely dull red. The observation refers to the exposed surface of the two sections of the resistor, the interior of each being much hotter.

The increase of resistance of G1, as compared with G2, continues till A, when the asbestos is placed over the former. It should be noted that the asbestos board did not come in contact with the resistor, but rested on the bricks, so that its only effect was to diminish the radiation of heat from G1. The result is a marked reduction in the resistance of G1, as compared with G2, although the resistance of the resistor as a whole was still increasing as is shown by Fig. 4. Here the increase in temperature has apparently more influence on the resistance than the formation of carbides. The removal of the asbestos at B does not show any appreciable effect. If the experiment is tried with a long resistor of granular carbon the effect of increasing or diminishing the radiation of heat is to cause distinct increase and decrease in the resistance.

When the weight is placed on G1 at C the diminution in resistance was so great that G2 then had a greater resistance than G1. Even after removing the weight from G1, the resistance of G2 was still slightly the greater. When the weight is placed on G2 at E, G1 again shows the higher resistance, and when the weight is removed at F the difference in the resistances is greater than before the weights were applied to either G1 or G2. It appears from this that the application of pressure to G2 produces a greater effect on the resistance than applying the same pressure to G1. This is confirmed at G, where pressure is applied to both G1 and G2, for the difference in resistance is further increased.

The weights were left on G1 and G2 for 8 minutes, and the curves show that during that time the difference of the resistances increased rapidly. This was probably due in part to the more rapid formation of carbides in G1 than in G2, and in part to the more rapid increase of the temperature of G2. Although on account of its greater resistance there was more energy developing in G1 than in G2, the temperature of the former was now so much the higher that the heat radiation was much greater and, consequently, the rate of increase in temperature was less than in G2.

The conclusions to be drawn from this experiment may be summarized as follows:

1. When the current is started there is first a rapid decrease in the resistance of the resistor, followed by a slow increase. Although the present experiment does not show it, this increase is followed by a decrease if the conditions are such that radiation of heat from the resistor is prevented and its temperature continues to rise.

2. Other things equal, preventing the radiation of heat from a carbon resistor cause a decrease in its resistance.

3. If pressure is applied to the resistor the resistance decreases, and after removing the pressure the resistance is lower than it was before applying pressure.

4. Of two granular carbon resistors, each composed of grains of uniform size, the coarser grained resistor has the lower resistivity.

5. If the same pressure is applied to a coarse grained and fine grained resistor the decrease in resistivity produced is greater in the former than in the latter. All of these conclusions are of importance in practical work where a granular carbon resistor is used. As was shown before, it is important to have some means of regulating the applied e. m. f. in order to compensate for the change in resistance.

When a current is passed through a carbon resistor its temperature will rise until the heat conducted away by the surrounding materials or radiated into space is equal to the heat generated. If the e. m. f. applied to the resistor is constant, then the watts will vary in an inverse sense to the resistance, and since the resistance varies in an inverse sense to the temperature, it follows that the watts eventually developed in the resistor will depend upon the rate at which heat is carried off. This is an important deduction, for it will be seen that it is possible to have two resistors composed of granular carbon of the same sized grains; to make the dimensions of the resistors identical, to apply the same e. m. f. to each resistor, and yet when a constant state is reached, one of them will generate much more heat per second, that is, use more watts than the other, simply because at first the rapid escape of heat is prevented.

A practical illustration of this is furnished by an experience of the writer which at first proved somewhat puzzling. A carborundum furnace was built in the usual way, with a resistor of granular coke. When the current was thrown on and the maximum voltage applied, it was observed that the resistance was somewhat lower than usual, for the ammeter showed that the furnace was taking a greater current than was to be expected. Under normal conditions the resistance of the core of a carborundum furnace decreases till the full amount of power for which the furnace is designed is used, and after that the voltage is regulated to keep the power constant, until finally a nearly constant resistance is reached. But in this furnace the resistance of the core, after decreasing to a certain extent, became constant long before the full power was generating in the furnace, and although the current was kept on for several hours there was no further change in the resistance. Inspection of the furnace showed that steam was coming off freely from the mixture which was quite warm, although the mixture in an ordinary carborundum furnace does not become warm on the outside till a considerable time has elapsed.

The explanation of the failure of the furnace to work was found to be that in making up the mixture of sand, coke, sawdust and salt for the furnace, wet sand had been used. No correction for the water in the sand was made, consequently there was a large excess of carbon in the mixture. This, combined with the presence of the water and the salt, made the mixture a fairly good electrical conductor, so that when the current was thrown on a large part of it leaked through the mixture. As a result, although on starting the furnace at the maximum voltage, the current passing was greater than usual and consequently the rate of generation of heat was greater, yet the temperature of the furnace did not rise sufficiently to bring the resistance of the core down to the working point. For as fast as the heat was generated it was lost by radiation or absorbed by the water to form steam.

In working with small furnaces it will sometimes be found that the resistance of the resistor will not diminish sufficiently to take the proper current, and this is often due to excessive cooling by radiation or conduction.

The influence of pressure on a granular carbon resistor must always be kept in mind. Suppose, for example, that the resistor is long, and that because of the design of the furnace, there is more pressure on one part than another. Then the place at which the pressure is high will have a lower resistivity than that at which the pressure is low and the temperatures will therefore be different.

Moreover, if the resistor is so designed that it has considerable depth, the lower part will be under greater pressure than the upper part, and consequently the heat generated below will be greater than above.

Since the experiment shows that the application of pressure to a granular carbon resistor produces a permanent change in resistance, even after the pressure is removed, it follows that

in constructing a resistor care must be taken to avoid packing the carbon down tightly in one place, and leaving it loose in another. Neglect of this precaution is a frequent cause of trouble.

The fact that a resistor composed of coarse grains of carbon has a lower resistance than one composed of fine grains, permits the adjustment of the resistance of the resistor to suit conditions as to the dimensions of the furnace and the available e. m. f. Staring with a resistor of solid carbon and proceeding by gradations to a fine granular material it is possible to obtain a great range of resistance.

While the effect of pressure, as shown by the experiment, is more marked when the resistor is coarse grained than when it is fine grained, this only applies to a limited extent. For carbon powder can be made an excellent conductor by judicious packing, and its use in this way is important. For example, in making contact between the granular carbon of a resistor and the terminals, finely powdered carbon, tightly rammed into place, is found to be very satisfactory. Graphite powder is, of course, much superior to amorphous carbon for this purpose, and probably the best material of all is found in the beautiful soft graphite obtained by the decomposition of silicon carbide.

Some of the considerations noted above only apply strictly to resistors composed of grains of carbon uniform in size. If a resistor is composed of carbon grains of a definite uniform size, it will have a certain resistance; but if the spaces between the grains are filled with finer grains of carbon, it is obvious that the resistance will be considerably diminished. In general it is better to use carbon grains of a uniform size in making a resistor, particularly if the construction is on a large scale, as the use of grains of different sizes make it difficult to obtain a uniform resistivity throughout the resistor.

Where resistors of greater resistivity than can be obtained from granular carbon are required it is necessary to mix with the carbon some other substance of high resistivity. The use of such a resistor is limited by the nature of the substance mixed with the carbon, since no other substance than carbon can withstand the highest attainable temperatures. The substance chosen should be very refractory, and for that reason a silico-carbide or silicon carbide seems at the present time to be most likely to give satisfactory results.

FLAME REGULATION IN CHEMICAL AND METALLURGICAL OPERATIONS.

By CARLETON ELLIS.

So widespread has been the interest manifested in certain new methods of combustion and flame regulation, known collectively as the Eldred process, that at the request of the editor of this journal the writer will give in the following article a statement of the general principles upon which the new process depends.

The Eldred process is probably the first effort ever made in the attempt at the simultaneous regulation and control of the duration of combustion, and of the temperature and volume of flame. From a given amount of fuel the process provides for the generation of the heat in any space desired, either large or small, filling this space with heat at an even temperature throughout. The major portion of heat is not generated in the furnace or fire box, but in the heating chamber itself and throughout all parts of it at the same time. On another hand, the heat can be generated in a localized spot in any part of this space.

The heat can be generated at a relatively low temperature if necessary, this being controlled by the regulation of the duration of combustion. A flame can be made so cool that it will not ignite wood, and may pass through all stages of heat intensity from this degree up to a flame which will melt fire brick, and the change from low to high temperature can be accomplished almost immediately at the will of the operator.

What we know about combustion has been almost wholly regulated by steam boiler practice. The prevalent idea of the conditions for satisfactory combustion is that the fuel must be burned in a pure air draft current with 50 to 100 per cent excess of air or oxygen. Such an excess of oxygen has been considered necessary for effecting complete combustion. A greater excess than this causes loss of heat energy by the sensible heat carried away in the escaping gases. Of course, the purer the air the better has it been regarded as a means for supporting combustion.

The ideas embodied in the inventions constituting the Eldred process are quite at variance with those above mentioned. The most radical departure involves the hypothesis that atmospheric air contains too high a percentage of oxygen for the economical combustion of fuel in many cases. As nature has not provided an atmosphere properly suited for combustion, it becomes necessary to create artificial atmospheres better adapted not only to maintain combustion, but to conduct it in such a way that the heat is applied at the point where it is most needed.

Previous to the advent of the Eldred process some attempt had been made to use coal in various arts, where low temperature flame was required, by extending the area of combustion and diminishing its intensity, but all of these practices with which the writer is acquainted have failed of their purpose, and while repeated attempts were made to use coal either alone or in combination with wood, they have been nearly all unsuccessful, and have failed entirely to accomplish the application of heat of low intensity in an economical way.

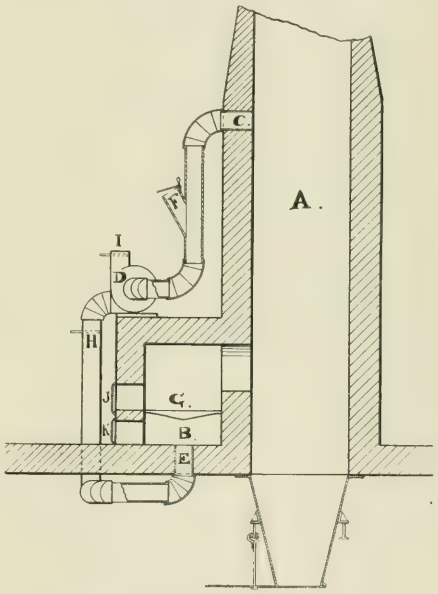


FIG. 1.—CONSTRUCTION OF APPARATUS

One of these methods was to employ a steam as a diluent, but steam has a very high heat constant, by reason of which it is able to absorb and carry away a considerable amount of energy as sensible and latent heat, and, inasmuch as fuel must be burned to produce steam, this did not generally prove practicable nor economical.

Another very common method in certain arts has been to open the ash-pit doors wide and flood the fire with cold air.

This, of course, is very extravagant of coal, because a large part of the heat, instead of being utilized in the kiln or furnace, is carried out by the air forced through the fire, so that while the fire burns out very rapidly indeed, the heat of the kiln is not high and much more coal is burned than is necessary; the efficiency of the process thus conducted being so low as to make it extremely wasteful.

For these purposes the inventor, Mr. Byron E. Eldred, substituted a mixture of atmospheric air and a neutral gaseous "diluent" as described in U. S. Patent 692,257 of February 4, 1902. The first installation of this process was made on some lime kilns at a plant near Philadelphia, and showed a very decided saving over old methods. Since that time most of the lime manufacturers in the country within reach of cheap coal have adopted the process and the economy in its use has been determined beyond a doubt.

The type of apparatus used is shown in Fig. 1, as applied to a lime kiln of the conventional type, G being a furnace communicating with a cupola A through an opening or arch. J and K are the fire and ash-pit openings, provided with suitable doors. A draft pipe or conduit connects at its upper end with A, through opening C, and at its lower end with the ash-pit B, through opening E, and has interposed in it a fan-blower D. That part of the conduit above the fan constitutes the suction pipe of said fan, and the part below the fan constitutes a delivery pipe therefor. A gate or valve H controls this delivery pipe. The fan has also an auxiliary outlet or delivery pipe I, controlled by a gate or valve through which a portion of the kiln gases may be disposed of without causing them to pass through the fire. At F the suction pipe is provided with an air inlet, also controlled by a valve. By adjusting this valve the relative proportion of air and kiln-gases in the draft may be exactly controlled.

The Eldred process, so far as investigated by the writer, seems to involve regulation of the composition and of the speed or volume per unit time, of the draft current of a furnace for the purpose of controlling the duration, temperature and volume of flame or of combustion. In its most characteristic application it involves the use of an artificially accelerated draft current, composed of air and a neutral gaseous diluent so proportioned as to retard combustion in the fuel bed and sufficiently accelerated to ensure a rapid and abundant evolution of combustible gases which, with suitable speed and dilution of the draft, may be developed into a long flame of large volume.

The diluent for the air consists of permanent gases which are neutral in so much as they are neither combustible nor supporters of combustion. In practice the waste gases of the process are always found to be sufficiently poor in oxygen to answer the purpose, and a portion of these is brought back from the stack and thoroughly mixed with such amount of fresh air as will produce the required percentage of oxygen in the mixture.

The process permits of wide regulation to attain desired results of various kinds under varying condition, and admits of many modifications, but in its most characteristic development the regulation is such that a flaming current of combustible gases and diluted air is carried to a distance before combustion is completed.

With a draft properly regulated for this purpose the furnace and fuel bed are cooler than with a pure air draft, and the body of diluent gases acts as an absorber and carrier of the heat of combustion which distributes this heat uniformly and lowers the temperature of combustion, but the more important action is that the liberation of the heat units of the fuel is greatly retarded and takes place at or near the material to be heated. In other words, the heat of the fuel is evolved at a point where it is needed, and where it can do direct work to the best advantage.

The *amount* and *velocity* of the draft current are closely interdependent factors with composition of the draft current and must be carefully regulated. This regulation therefore should be with a view to best practice of the process and not to saving of heat units of the waste gases. The amount of the diluent draft current and its velocity through the fuel bed should be such as to force the inflated current of slow-burning combustible and diluent gases onward to the regions and material to be heated before they are burned out. On the other hand, economical practice of the process requires that they be given opportunity to burn out before reaching the return conduit. In order that the gases may burn out, the regions traversed by them should be such as not to chill them before there has been time to effect a complete union of the diffused combustible elements and oxygen, for otherwise much carbon monoxide will pass into the stack and will be largely wasted as the gases recovered and brought back to the fire are only a small fraction of the whole.

For the reason just stated the process is especially useful in arts, like lime burning, where the gases travel for a long

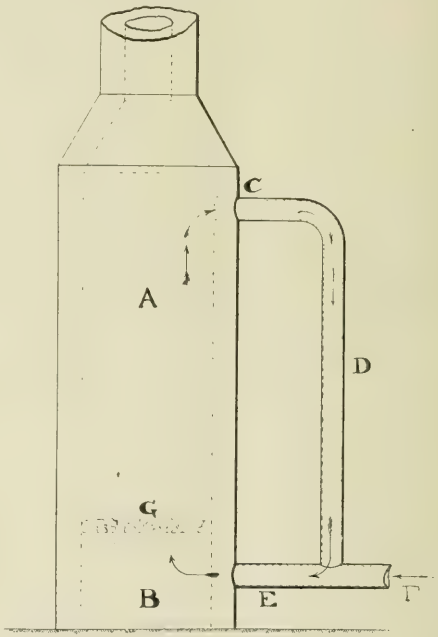


FIG. 2.—GAS CYCLE.

distance in the highly heated rock, and are thus kept for a comparatively long time at a high temperature favorable to complete combustion.

In a lime kiln, or in any furnace where the gases can pass unchilled, they carry the heat in potential form and evolve the heat where it is needed. The advantage of such a process over those where the heating is accomplished partly by convection, but mostly by conduction, is obvious. The process is very flexible, and by proper adjustment the flame may be varied from the localized intense heat of the ordinary forced draft of pure air to the long, slow, more characteristic flame of the Eldred process, which, in an extreme case, may be made so cool as not to ignite wood.

The Eldred process involves a cyclic return of a portion of the waste gases, and this has lead to numerous inquiries as to just what effect such a cycle of travel has upon the constitution of the escaping gases. To illustrate the questions involved in the so-called "gas cycle," reference is made to Fig. 2. In this diagram A represents a chamber filled with the material to be heated. A determined portion of the products

of combustion are drawn out at C and are carried back through C, D, E to ashpit B. A measured amount of air is admitted at F. The gas and air mingle and pass through the grate and fire box G. At the start the burned gases coming from the carbon fuel and passing up the stack normally contain nitrogen 79 per cent, oxygen 15 per cent and carbon dioxide 6 per cent. Suppose a portion of these "normal" gases to be drawn back at C and to mix with an equal amount of air from F, then the gas entering at E will contain oxygen 18 per cent and carbon dioxide 3 per cent, the nitrogen, of course, remaining substantially unchanged. These pass through the fuel and, it is assumed, burn the same amount of carbon as represented by that in the "normal" gas, or the equivalent of 6 per cent carbon dioxide.

The following table shows the progressive changes in the character of the entering and escaping gas. The nitrogen remains practically constant, namely, at 79 per cent, so it need not enter into the calculations.

Interval of Time.	Gas Discharged at Top of Kiln		Gas-Air Mixture Entering at E	
	Oxygen.	Carbon Dioxide.	Oxygen.	Carbon Dioxide.
	per cent.	per cent.	per cent.	per cent.
0	15	6	.....	.....
1	12	9	18	3
2	10.5	10.5	16.5	4.5
3	9.75	11.25	15.75	5.25
4	9.375	11.625	15.375	5.625
5	9.1875	11.8125	15.1875	5.8125
6	9.0938	11.9062	15.0938	5.9062
The limiting values therefore are				
	9	12	15	6

Or, in other words, the application of such a cyclic process, starting with stack gases carrying 6 per cent of carbon dioxide and continuously diluting these with an equal volume of air (calculated at the same temperature), would cause the percentage of carbon dioxide in the stack gases to increase to 12 per cent, or double its normal amount, and the oxygen would be reduced to 9 per cent, or the excess air expressed in percentage of that chemically combined would be reduced from about 250 per cent to approximately 75 per cent excess, a difference of 175 per cent. In many furnaces 80 per cent of the heat generated is carried away in escaping gases. Could such a case as above described be carried out in practice, the reduction in the excess air by 175 per cent would be equivalent to an increase in fuel efficiency of about 40 per cent. The variable nature of the fire, among other things, in practice does not, of course, permit of an adjustment so effective that the above conditions can be realized. Besides, the Eldred process uses to advantage a smaller fraction of the stack gases than that above mentioned.

According to the theory of limits, equilibrium in this system is never attained, but actually it is quickly reached so far as can be shown by analysis of the gases at different points.

In calculating the gas-air mixture required per pound of coal, one has to take into consideration two factors. First, that less oxygen by volume is present than in ordinary air, and, secondly, that less excess oxygen actually is required with the Eldred process. A slow drawn-out combustion seems to require less excess oxygen for its completion than a rapid combustion.

The following formula serves for calculations. The cubic feet of gas-air mixture A required per pound of coal allowing no excess is:

$$A = \frac{32(T + 440)}{5\Theta}$$

where T is the temperature and Θ the oxygen content of the gas-air mixture entering the furnace.

By suitable regulation of the draft in accordance with the above principles and by subsequent treatment, the resulting gas current or flame may be adapted to a wide variety of uses without loss of any of its characteristic advantages and economies. A large number of these uses have been tried and are now in successful practical operation. The results have shown unexpected special advantages in almost every case.

It is in successful operation on billet-heating and annealing furnaces, on lime, cement and brick kilns, on ore-roasting, reverberatory furnaces, etc. It may be used in puddling mills, rolling mills, in ceramic work and in many other arts. A recent ingenious modification of the process makes it applicable to steam boilers, to which it has been heretofore unsuited.

RESULTS OBTAINED WITH THE ELDRED PROCESS.

Lime Burning.—As applied to lime burning in the ordinary way, a ton of coal will burn only about the same amount of lime as a cord of wood, although the former has more than twice the heat energy of the latter. With the Eldred process the full heat value of the coal is obtained and a ton of coal will produce from 2 to 2¼ times the amount of lime that is now produced from a cord of wood. On dolomite rock as high an average output as 200 barrels per day of lime has been obtained from a single kiln. One firm reports a saving of $50 per week per kiln by the use of the process.

The Eldred process gives as high an efficiency as 5¼ pounds of lime per pound of coal burned. This means that more than 85 per cent of the coal is used in the actual calcination of the lime stone, while less than 15 per cent is lost in the sensible heat of the escaping gases and through radiation.

The output of a kiln may be increased at least 50 per cent over that of any other known method, by the application of the Eldred process in conjunction with induced draft. The latter, by itself, will not give satisfactory results, as the fire becomes intensely hot and overburns the lime. By the use of diluent gases the fire will be tempered to the proper calcination point, and the flame increased enormously in volume, with the result that the output of the kiln shows a gain of more than 50 per cent. The Eldred process gives a lime product of great uniformity. This is because the nature of the flame is such that there is no danger from overburning the lime. That is to say, the heat never need reach the point where the silica usually found in lime stone fuses with the lime to form vitreous silicate of lime. Such a vitrefication cannot be avoided in the ordinary coal fire, and the result of this overburning often proves disastrous, as the silicious particles so produced do not slake out immediately like quick lime, but only after the elapse of several months. When they do slake, the plaster or mortar is fractured and the walls of a building are thereby given a most unsightly appearance. The Eldred process overcomes this heat localizing tendency of the ordinary coal fire, and gives rise to a long flame of low heat intensity which brings about the uniform calcination of lime in a most efficient and economical manner.

The diluent gases retard combustion on the grate and carry the generation of the heat into the body of the stone. Knowing these facts an engineer would predict a long life for the furnace and grates. Such is the case. The method reduces repair bills to an exceedingly low figure. In the saving on repairs alone a kiln will in one year's time fully pay the cost of the installation.

Iron and Steel Industry.—Regulated and adapted to the conditions of heating furnaces used in rolling mills, the process gives a very mellow heat. The iron or steel is easily worked and the product is of unusually good quality, and there is a saving of about 25 per cent in fuel as well.

The annealing of iron is perfectly done with a fuel saving of 20 to 30 per cent. The iron is especially well annealed under this process, owing to the long, even flame of uniform

temperature which surrounds the annealing cases or boxes. The flame has less oxidizing action upon the latter than does the ordinary fire. It is quite out of question to use steam for regulating the fire temperature, owing to the resulting oxidizing action. The use of an inert gas overcome this difficulty.

Cement.—Cement burning is another wide field to which the Eldred process has been adapted and in which it has been found to be of value, as tests recently made demonstrate that on rotary kilns the coal is reduced from 20 to 40 pounds per barrel of cement produced. The high temperature required in the clinkering zone is easily obtained. In fact, with the Eldred process the writer obtained a temperature of 3150° F. in a cement kiln, as registered by a Wanner Optical Pyrometer; 2700° F. is the highest temperature actually needed.

Brick Burning.—In the burning of brick we have conditions somewhat similar to those obtaining in a lime kiln. A voluminous flame of uniform temperature is desired. A high temperature such as would result from using a forced draft of pure air overburns the brick adjacent to the fire box, causing a considerable loss from "rejects." The use of a diluent gas overcomes this difficulty. This, together with a better application of the heat has resulted in a saving of over 50 per cent in the cost of burning brick. In one instance which was brought to the writer's attention, the time of burning was reduced from 17 to 11 days, and the product was of much better quality than that ever before manufactured at the plant in question.

Metallurgy.—In metallurgical work and ore-roasting remarkable results have been obtained. Ore roasted with this process is more easily leached, so that a more thorough extraction is obtainable. On account of the even flame and low temperature, continually maintained, the sulphur of the ore is more thoroughly oxidized, and there is less fusion and formation of slag difficult to leach. The saving in fuel on the average amounts to 40 per cent, and it has never, to the writer's knowledge, fallen below 25 per cent, and, if to this item is added the saving from better extraction and from reduction in labor, the economy reaches a very high total.

Correspondence.

THE LIMITS OF PHYSICAL SCIENCE.

To the Editor of Electrochemical Industry.

Sir—I accept the opportunity offered to discuss further the topics considered in the editorial "On the Reality of Atoms and Ions," which appeared in the November number of this journal.

With much that is said in that editorial, and especially with the quotation from Maxwell, I am in hearty accord. The essential difference between the author of the editorial and myself appears to be that I believe we may attain and, indeed, have attained positive knowledge with regard to some matters which lie beyond the limits of sense-perception, while he, apparently, has no such belief. In using the term "positive knowledge," I mean that we may obtain knowledge which differs in *degree*, but not essentially in kind from our knowledge of physical laws and of physical facts. From the standpoint of philosophy we have no positive knowledge of anything outside of ourselves. Everything which comes to us through sense-perception requires more or less of interpretation before it can become a valuable part of our mental property, and such interpretation is always liable to error. It is only because our successive interpretations are consistent with each other and with the interpretations of others that we acquire a conviction of the existence of a universe external to ourselves, which is well-ordered and uniformly consistent with itself.

Some chemists and physicists appear to think that there is an essential difference in *kind* between knowledge of physical laws and the knowledge which we gain by inductive processes, as, for instance, our knowledge of atoms, and that the former knowledge is positive, while the latter is not. That physical laws are like the atomic theory in being only an interpretation, and that the two do not differ in their essential nature, but that they differ chiefly in the complexity of the concepts involved will, I think, be clear from an illustration.

At the close of the nineteenth century it was universally accepted as a law of nature that one element could not be transformed into another. Facts recently discovered have raised very grave doubts of the universality of this law. It is evident that the law is only an interpretation of the facts which were known, and that it is subject to a revision, which is similar to the revision and amplification which the concept of atoms has undergone at the hands of chemists and physicists for the past one hundred years. Our interpretation may correspond very imperfectly with the reality, but that there is some approach to the truth I firmly believe.

A sentence in Mendeleeff's "A Chemical Conception of the Ether," a translation of which has just appeared, is so apposite that I cannot refrain from quoting it. He says: "Although skeptical indifference is prone to discern only a 'working hypothesis' in the conception of ether, yet the earnest investigator, seeking the reality of truth, and not the image of fantasy, is forced to ask himself what is the chemical nature of the ether." I am quite willing to put myself beside Mendeleeff as one of those who "seeks the reality of truth," while I am fully aware that the search is a long one, and that the goal is to be reached only through countless years, during which we can see only imperfect truth.

William A. Noyes.

Bureau of Standards, Washington, D. C.

SYNOPSIS OF ARTICLES IN OTHER JOURNALS

A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.

Industrial Electrochemistry and Electrometallurgy.

Production of Ozone by Silent Discharges.—In view of the increasing interest which the production of ozone from atmospheric air attracts at present for the industrial purposes of sterilizing water and bleaching, an article by A. W. Gray, published in the *Physical Review* of November, should be of interest. Though his investigation was mainly undertaken to test Warburg's theory of the Siemens & Halske ozonizer and to improve the construction of the latter, yet some results obtained by him are of more general interest. As ordinarily constructed, the effective part of a Siemens ozonizer consists of two coaxial cylindrical shells of glass separated by a layer of the gas to be submitted to the action of the electric discharge—the whole forming a compound condenser of three layers. The author modified the construction as shown in Fig. 1. The effective portion that comes between the electrodes is of large diameter, with thin walls as close together as possible, and short enough to permit a flow of gas sufficiently rapid to

prevent the concentration of ozone from becoming so great that the deozonizing action of the electric discharge pointed out by Warburg would have an appreciable effect. The remainder of the generator is of thicker glass. Interior insulation is secured by extending the gas space above, and by reducing the diameter there; and the flow of gas is facilitated by increasing the distance between the walls in the upper portion as well as by providing a considerable space at the bottom. That the insulation thus obtained was effective, even when considerable water-vapor was present in the oxygen, seems clearly indicated by the results obtained by the author. External surface insulation is increased by carrying the conductor to the inner electrode down through a narrow glass tube sealed in the neck as indicated. As an additional precaution a metallic guard ring connected to earth surrounded the neck of the generator just below the gas exit. The electrodes were of silver, deposited on the glass in order to avoid strains which would be caused by the employment of a liquid.

FIG. 1.—OZONIZER.

An interesting result found by the author is that the mass of ozone produced per coulomb sent through the gas increases with the potential difference applied between the electrodes of the generator, and that the increase in the former is apparently directly proportional to the increase in the latter. A number of experiments were made to determine the effect of considerable water vapor on the production of ozone. It was always found that under such circumstances the yield of ozone per coulomb sent through the gas was from ten to fifteen per cent less than when well dried oxygen was employed with the same potential difference between the electrodes of the generator. And here, too, there seemed to be indications that, as long as the gas remained under the same conditions, the increase in the yield of ozone was directly proportional to the increase in the potential. The results which the author draws from his investigation with respect to the production of ozone for technical purposes are summed up by him as follows:

First, good surface insulation of the generator, both internal and external, by means of such device as described above (Fig. 1).

Second, dry oxygen.

Third, charging and discharging as sudden as possible. For this reason the resistance and self-induction of the circuit should be reduced to a minimum, and it is also possible that operation by connection with a Leyden battery might yield better results than the ordinary method of employing an induction coil or an alternating-current dynamo, as these machines could not give such a rapid change in the potential difference between the electrodes. Merely placing the generator in parallel with the spark-gap of an electrical machine, as was done by Shenstone and Priest, is ineffecient, because the charging takes place so slowly that no illumination, and consequently no ozone, is produced.

The Electric Furnace in the Zinc Industry.—The October issue of *L'Electrochimie* contains a rather long paper by SALGUES on the treatment of zinc ores in the electric furnace. He describes three different applications. The first is for making zinc powder. In this case all the zinc minerals, whatever their nature, are mixed with coal as reducing agent, and charged into the electric furnace; the zinc vapors are then greatly diluted by CO gas, and only zinc powder is obtained. The second application is for making solid zinc. This may be done by three means. (a) The zinc is distilled in form of concentrated vapors; this necessitates two furnaces; in the first the zinc is reduced at a sufficiently low temperature; in the second—the electric furnace—the zinc is distilled. (b) Only the electric furnace is employed, but the operation is carried out at a temperature sufficiently low to prevent the distillation of the zinc; it is obtained in liquid form below the slag; of course, a resistance furnace is to be used in this case. (c) "The third process involves a partly electrolytic principle. The minerals are first preliminarily reduced at a low temperature, but without being mixed with carbon; the reduction is accomplished exclusively by means of carbon monoxide. This means that the zinc silicate remains unchanged, since it can be reduced by solid carbon only. After this reduction the minerals are charged into the furnace. The fusion zone is regulated for the production of a very fusible slag, in view of the operation at low temperature. The electrical heat is produced simply by the Joulean effect. The fusion of the zinc, obtained from the preliminary reduction of the oxide is accomplished in the same way as in case (b); the metal collects below the slag. The zinc silicate is electrolyzed. For this reason the furnace is operated, not with alternating, but with direct current, in such a way that the zinc is obtained in the same way as aluminium. Very little zinc powder is obtained." The author gives some notes on the construction of the furnace, and of the condenser for getting powdered zinc; he also points out the advantages which the electric furnace has in zinc metallurgy. He finally deals with the production of zinc white.

Nickel.—A summary of the development of electrolytic processes for the production of nickel is given by J. HESS in the *Zeit. f. Elektrochemie*, October 14, mainly on the basis of articles published in ELECTROCHEMICAL INDUSTRY. The summary contains nothing that is new to our readers, with the exception of the following remark, which should prove interesting. "The Browne process shows that the electrolytic separation of nickel and copper from chloride solutions was possible and successful without getting chlorine as an end product. This justifies the expectation that a well-developed method using sulphate solutions should also be successful. We may, perhaps be later in a position of reporting on such a process by Schuckert & Co."

Electrometallurgy.—In a continuation of J. IZART'S serial in *L'Industrie Electrique*, August 25, nickel and lead are dealt with. The author considers very briefly the methods of separating nickel and copper from nickel-copper matte, and refers to the refining of nickel in order to recover the precious metals contained in commercial nickel. He then deals with the Salom process of reducing lead, and the Betts process of refining lead.

Electric Glass Furnaces.—In the *Elektrochem. Zeit.* of October, J. BROWN begins to give an illustrated summary of the various electric furnaces patented for glass manufacture. In 1881 Reich & Co. (German patent 17,736) devised a method of smelting glass electrically on a small experimental scale. Askenasy (German patent 917,328, 1896) let the electric arc play over the surface of bricks and pottery ware to produce a glazed surface. Becker, a German glass manufacturer, became interested in the use of electric smelting in 1897, and took out several German patents (101,176, 138,416). The first experiments were made with Becker's furnace in Cologne in 1900. Luehne took out two English patents in 1899 (23,090 and 24,148). Several modifications of the Becker process were patented by Voelker (German patents 134,035, 124,702, 128,250, 131,291). The article is illustrated by diagrams, taken from the patent specifications, and is to be continued.

Plating Sheet Zinc with Nickel.—In the *Journal de l'Electrolyse* of October 15, M. BRANDELY makes some remarks on the plating of sheet zinc with nickel and the use of nickeled sheet-zinc as a substitute for sheet iron plated with tin for certain purposes. The zinc is coated only on one side with

nickel. He insists especially on the careful cleaning and preliminary preparation of the surfaces before they are plated. The zinc surface is first very carefully polished, freed from grease and washed, and then coated with copper, either on one or on both sides and then again washed. This is followed by the process of plating with nickel. The composition of the solution preferred by the author is double sulphate of nickel and ammonium 600 grams, sulphate of ammonium 100 grams, boracic acid 250 grams, and 10 liters of distilled water. The current density is 1.2 amperes per square centimeter of surface to be nickeled. The plates are then washed and polished.

Nitric Acid from Air.—In the *Elektrochemische Zeit.*, of October, O. Kausch gives an illustrated summary of the various processes which have been proposed for the fixation of atmospheric nitrogen by means of electric discharges. Besides the experiments of Cavendish and Lepel the following processes are described on the basis of patent specifications: Naville and Guye, Prim, Siemens & Halske, McDougall, Bradley and Lovejoy, Birkeland and Eyde, Kowalski.

Theoretical and Experimental.

Temperature Measurements up to 1600° C.—A. L. Day and E. T. Allen have recently prepared in the laboratory of the United States Geological Survey, apparatus for generating, regulating and measuring temperatures up to 1600° C., which has proved easy of manipulation and uncommonly exact. It is, in effect, a reproduction of the Reichsanstalt high temperature scale. The temperatures were measured with thermo-elements exclusively. The authors obtained from Heraeus, Hanau, Germany, a set of four elements cut successively from the same roll of wire, which, when joined together, proved to be identically alike in their readings over the range of temperature covered by the gas scale of the Reichsanstalt (250° to 1150° C.), within the limits of observation error. They were taken to the Reichsanstalt and measured in the original melting-point furnace with the same elements in terms of which the gas-thermometer scale has been expressed, and five careful comparisons were made. These were the melting points of cadmium, zinc, antimony, silver and copper. The elements were then taken by messenger to Washington and further compared in an electric furnace, which will be described below, and the melting points of the same group of metals again determined. The metals used, however, were from other sources than those which had served for the calibration at the Reichsanstalt. When the test was finished, the authors were enabled to assure themselves that, although all the constants in the measuring apparatus—thermoelements, resistances, standard cells, metals, etc.—had been changed in the transfer from the Reichsanstalt to the Geological Survey at Washington, the aggregate error nowhere exceeded 1° over the entire range from 250° to 1150°. It will be remembered that 1° was the accuracy which the standard gas thermometer showed at 1000°. The thermoelectrical system of the authors is, therefore, now doubly established—(1) by direct comparison and (2) through an independent series of metal melting points—upon the gas thermometer scale of the Reichsanstalt within the limits of error of the latter, and can be verified at any time with the help of two of the elements which have been laid aside for this purpose, or by means of the melting points of the metals. The scale is therefore permanent. The four metals which were used in Washington for fixing points of the temperature scale were cadmium, zinc, silver and copper. The cadmium and zinc were taken from the regular listed chemicals of Eimer & Amend (zinc, "C. P. in sticks; cadmium, metal sticks"), the silver was the well-known test silver of the Philadelphia Mint Laboratory, while the copper was also from Eimer & Amend ("C. P. copper drops cooled in hydrogen"). The melting points, as determined by the authors are as follows, the figures given in parenthesis representing the corresponding temperatures determined in the Reichsanstalt. Cadmium 321.7 (321.7), Zinc 420.0 (419.0), silver 962.2 (961.5), copper in air 1065.3 (1064.9), copper in reducing atmosphere 1083.6 (1084.1).

Four more elements were later prepared and calibrated in the same way. Of these, two are of the usual form (Fig. 2), and two are of a new design (Fig. 3), which has proved very effective in the determination of the melting points of non-metallic substances. It will be seen from the diagram of the insulated element that the hot junction is protected from the melting charge by a casing of platin-iridium (0.1 mm. thick) and by a protecting tube of refractory Berlin (Marquardt) porcelain (1.5 mm. thick). Very early in the experiments upon the mineral silicates the authors became aware that the conductivity of these minerals for heat would be much poorer than in similar charges of metal. Furthermore, the charge of mineral which the furnaces could carry was only one-fourth to one-third as great as the metal charges used in the calibrations because of the great difference in specific gravity and the limited space which could be heated to a fairly uniform temperature. For these reasons the changes of state would be less sharply marked upon the heating and cooling curves than melting points, and it was feared that the readings of the protected element might prove too high or too low through inability to take on the temperature of the surrounding mass promptly. To obviate this possible source of error, the form of thermo-element indicated in Fig. 3 was devised. It really amounts to nothing more than the ordinary form of platinum—platin-rhodium element with the platinum wire insulated from the other by a very slender porcelain (Marquardt) tube and the platin-rhodium wire broadened out and wrapped around this tube like a cap over the portion which dips into the charge. The hot junction is then the lower extremity of the cap where the platinum wire emerges from its insulating tube and is welded inside the platin-rhodium cap.

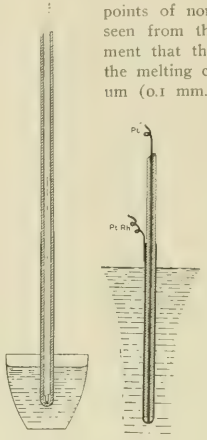


Fig. 2. Fig. 3.
THERMO-ELEMENTS

The furnace, in plan, differed but little from that in use for melting-point determinations at Reichsanstalt. In the working out, two important changes were introduced, in order to enable it to reach the higher temperatures of the mineral melting points. A more refractory and better insulating material was substituted for fire-clay in the hotter parts and the coil was wound on the inside of the oven tube instead of outside. A diagram of the furnace in section is shown in Fig. 4. It could be used for any temperature up to 1600° C. without any difficulty or especial precautions, and could be regulated to maintain a constant temperature at any particular point for long periods of time. The coil, which was obtained from Heraeus, was of platin-iridium wire (90 parts Pt, 10 parts Ir), 1.5 mm. in diameter, and required about 3000 watts to maintain a constant temperature of 1600° C. The furnace was car-

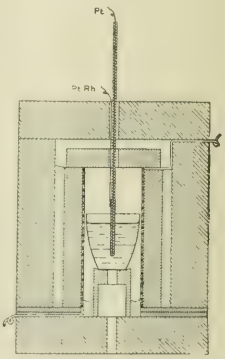


FIG. 4.—ELECTRIC FURNACE.

ried at times on a 110-volt direct-current street main, but accurately constant temperatures could not be depended upon without a storage battery.

Electrolysis of Acid Solutions of Aniline.—When hydrochloric acid is electrolyzed, chlorine is set free at the anode, and, as L. Gilchrist remarks in a paper in *Jour. of Phys. Chem.*, November, it seemed quite feasible to dissolve a little analine in the acid and let it be converted into chlor-aniline by the chlorine set free, just as the soda in the electrolysis of salt solutions is converted into hypochlorite. When he made this experiment, however, aniline black—one of the oxidation products of aniline—was formed. The reason is that the liberation of chlorine requires 1.25 volts, while the formation of aniline black form 0.1 n aniline in solutions of n-hydrochloric acid or n-sulphuric acid takes place at 0.95 volt (small anode, hydrogen cathode). Therefore, only traces of chlor-aniline are formed. On the other hand, since the oxidation potential of aniline (0.95 volt) lies above the decomposition voltage of hydrobromic acid (0.75 volt in 4n — HBr), on electrolysis of a solution of aniline in hydrobromic acid bromine is liberated and aniline black is not formed, but bromanilines. The oxidation potential of m-nitraniline in sulphuric acid solution (1.43 volts) is much higher than that of aniline.

Deposition of Aluminium from Ethyl Bromide Solution.—The full account of H. E. Patten's investigation of this subject, which was noticed in our October issue, page 413, is to be found in the November number of the *Jour of Phys. Chem.*

Electrolysis of Potassium Acetate.—With respect to the paper of Foerster and Piguet, abstracted in our November issue, page 459, some critical remarks are made by H. Hofer and M. Moest *in the Zeit. f. Elektrochemie*, October 21. The former authors are said to have overlooked the formation of methyl alcohol in the electrolyte.

Passive State of Metals.—An article by O. Sackur on the anodic solution of metals and the passive state is found in the *Zeit. f. Elektrochemie*, October 28. The author makes some remarks on the passive state of zinc and states that it can be explained neither by Faraday's oxide film theory nor by the valence theories of Finkelstein and Mueller. His own views are essentially as follows. Between a bivalent metal and any aqueous solution an equilibrium is quickly established according to the equation $M + 2H^{\cdot} \rightleftarrows Me^{\cdot\cdot} + H_2$. With metals which do not decompose water—and only these can become passive—the discharged hydrogen cannot be developed as gas, since it has not atmospheric pressure or the required overvoltage. The solution of the metals, to form ions, can therefore continue only to the equilibrium concentration, if the discharged hydrogen is not continually removed. This takes place quickly, for instance, by reaction with Cl ions, if they are present. But the combination with anodically discharged oxygen may be very slow. The speed of this reaction depends on the catalytic action of the metal. The author, therefore, concludes that the capability of metals to become passive must be the greater the smaller their catalytic action on the combinaion of hydrogen and oxygen. He considers this view as a useful working hypothesis.

Influence of Inert Ions on the Electrolytic Formation of Periodates.—In the electrolysis of neutral solutions of iodates with polished platinum anodes, the quantity of periodate formed is in general very small, but can be largely increased by the addition of indifferent ions. A paper on this subject is contributed to *Zeit. f. Elektrochemie*, September 23, by E. Mueller. We have two means for increasing the ampere-hour efficiency of the electrolytic oxidation of iodic acid—which, if there are no additions, is never more than 1 per cent with a polished platinum anode. One means is to use platinum as anode and to add a fluorine ion to the electrolyte (for instance, in the form of potassium fluoride). The other means is to use pure iodic acid without any addition, and to substitute a lead peroxide plate for the platinum anode. Both means increase the oxidation, but the addition of the lead per oxide acts by decreasing the "reaction resistance," while the action of the fluorine ion is due to an increase of the anodic potential. One may say that the fluorine ion increases the "anodic overvoltage" of the platinum. This shows that the overvoltage depends on the nature of the electrolyte.

Preparation of Persulphates.—A similar beneficial effect of the presence of fluorine ions has also been observed by E. Mueller in the electrolytic preparation of persulphates. His experiments are described in the *Zeit. f. Elektrochemie*, September 30.

Preparation of Chlorates.—With respect to a German patent of Siemens & Halske on thte beneficial effect of fluorine ions on the electrolytic production of chlorates, F. Foerster and E. Mueller show in the *Zeit. f. Elektrochemie*, September 30, that this effect is absolutely different from that described in the preceding two abstracts. In general, slight acidulation of a chloride solution causes secondary formation of chlorate, decreases the attainable content of hypochlorite and the anodic development of oxygen and increases the output of chlorate. What Siemens & Halske do is simply to acidulate the sodium chloride solution by addition of hydrofluoric acid.

The Influence of the Cathodic Material on Reduction.—The important part which the nature of the cathode material plays in the electrolytic reduction in general and especially in the reduction of aromatic nitro-compounds, is well known. The effect produced depends on the cathode potential, and a certain reduction energy corresponds to a given cathode potential (Haber). In this connection a paper by W. Loeb and J. Schmitt, published in the *Zeit. f. Elektrochemie*, September 23, is of interest, dealing with the influence of the cathode material upon reduction of m- and p- nitrotoluene. The reduction is smallest for nickel cathodes and increases for cathodes of the following materials in the order mentioned: Zinc, copper, copper together with copper powder.

Freezing Point of Highly Saturated Salt Solutions.—With reference to a recent investigation of H. C. Jones and F. H. Getman, a note is published in the November issue of the *Journal Phys. Chem.* by L. C. de Coppet on work done by him, as early as 1871 and 1872, on the molecular depression of the freezing point of water, produced by some very concentrated salt solutions. For some salts the molecular depression of the freezing point reaches a minimum with increasing concentration to increase again afterwards, while other salts exhibit a continuous decrease in the molecular depression as the concentration increases. More than thirty years ago he showed that the continuous decrease may be explained in two ways; first, by the dissociation of hydrates formed by the solute at the expense of the solvent; second, by dissociation of the solute, probably hydrolytic dissociation.

Action of Amalgams upon Solutions.—In the *controversy* between G. Fernekes and G. McP. Smith (pages 67 and 201 of this volume), Fernekes again takes the floor in the November issue of the *Jour. of Phys. Chem.* He denies that the electrolytic dissociation theory can be harmonized with the facts under discussion, while he thinks they may be simply explained on the basis of Kahlenberg's views.

Very Small Ionic Concentration.—F. Haber's paper on this subject, abstracted in our August issue, page 320, has brought about an interesting discussion in the columns of the *Zeit. f. Elektrochemie*, as was to be expected. The issue of August 12 contained three papers by G. Bodlaender, R. Abegg and H. Danneel who propose several hypotheses to defend the reality of the extremely small ionic concentrations in question. F. Haber replies in the issue of September 30.

Miscellaneous.

Tin-Lead Alloys.—L. Peetz gives in *Metallurgie* for June 22 and 29, the results of extensive researches which he has made for the purpose of discovering a means of producing

pure tin from these alloys. He directed his search towards finding a flux which would take up the lead and leave the tin. This he found to be partially, but not completely, accomplished by melting in the alloy, and agitating with it, a double chloride of tin and potassium. While the lead attacks this flux, yet there was always some left in the tin, and there was always loss of tin chloride by volatilization, so much as to make the method commercially impracticable. We think it quite likely that an electrolytic method of refining could be easily devised for this alloy, the problem being to find an electrolyte which does not attack as anode material either one of the two metals, and dissolves the other. However, another commercial principle intervenes, at least in this country, which is that there is such a large use for lead-tin alloys as solders that thousands of tons of pure lead and tin are melted together annually to make them, and there is really no need or use for a commercial process for separating them.

Study of Alloys.—E. S. Shepherd, in the *Iron and Steel Magazine* for September, calls attention to some neglected details in the experimental study of alloys. His criticism, which is perfectly just, is that several recent papers on this subject have lost much of their value, because the work did not include *all* the secondary changes which can be noted by the pyrometer, when studying cooling curves, but was limited simply to giving the freezing-points. The other points of arrest, marking the separating out of eutectic mixtures, or changes of molecular structure, occurring below the freezing point, are of primary importance in connection with the microscopic study of these alloys, and where these have not been included in the observations, the work will have to be done over. Another criticism is the lack of proper stirring, while determining freezing points, rendering possible errors of 40° or 50° because of surfusion. The densities of the alloys are also data of considerable importance, and easily determined, yet most investigators neglect the assistance which may thus be obtained. The article closes with the regret that more determinations of the specific heats and heats of formation of alloys are not being made.

Soldering Aluminium.—This question, which is of great importance for the application of aluminium for various purposes is discussed by Millet in *L'Electrochimie,* October (from *La Métallurgie,* April 13). He gives two compositions of a solder. The first has a melting point sufficiently high to stand the heat necessary for "mercury gilding;" it consists of 30 parts Al, 13Ag, 6 Cu, 45 Cd, 3Sn, 3Zn. It is made as follows: First an alloy of 20 parts Al, 13Ag, 6 Cu is made in a crucible and cast into ingots. This alloy is added to a second alloy, while in fusion and consisting of 10 parts Al and 30Cd. To the mixture is added the balance of 15Cd, 3Sn, 3Zn. The melting of the second alloy and the mixture of the two alloys has to take place at a temperature not above dull red. A second solder, for ordinary purposes not requiring high temperatures (since its melting point is at 300° C.) consists essentially of equal parts of zinc and cadmium, and is made as follows. The zinc is melted in a crucible and the cadmium is added. To this alloy is added a 50 per cent copper-aluminium alloy in various proportions, according to the resistance desired; the maximum amount of the Cu-Al alloy is 5 parts per 95 parts of the Zn-Cd alloy. No flux is required with either solder.

Iron and Steel Institute Papers.

The recent international meeting of the Iron and Steel Institute brought to our doors some of the best-known metallurgists of the world, and we are certain that they have returned to their homes with very vivid recollections of American hospitality. At the two meetings for reading of papers, held at the Hotel Astor, New York, on October 26 (a few days too late to be reported in our issue of November 1), there were read several interesting and valuable papers. The following abstracts are made from advance copies of the papers.

C. V. Bellamy, director of public works at Lagos, gave a long account of "A West African Smelting House," with photographs and most unique details of this primitive method of reducing iron ore. Some analyses of the ore, slags and products, made by F. W. Harbord, show the operation to be a direct process, the metal being reduced by charcoal and subsequently partly decarburized in the same furnace by means of fusible oxides, which largely dephosphorize the metal. The character of the community, their enthusiasm for, and pride in their work, and particularly their contempt for the inferior European iron, make interesting and amusing reading.

A. McWilliam and W. H. Hatfield presented a paper on "Acid Open-Hearth Manipulation," in which the general results of Brinell on the action of manganese, silicon and aluminium in producing sound ingots were confirmed, *i. e.*, that silicon is relatively 5.6 times as efficient as manganese, percentum for percentum, in increasing the soundness of ingots, and aluminium 28 times. Besides this, details were given showing that the rate at which silicon is oxidized and removed from a bath of steel depends as much on the character of the slag on the bath as on the intensity of the oxidizing influences; that by making a slag suddenly highly siliceous the silicon, which before that was falling, afterwards commenced to increase, although the furnace had been cooled off somewhat by the siliceous additions. The conclusion to be drawn from these results is that a fifty-ton bath of steel covered by slag and heated by white-hot gases, is no exception to, but only a complex example of, the laws of chemical equilibrium; that a suitable slag which, so to say, invites silica is a predisposing attraction which helps to determine the oxidation of silicon; that a slag high in silica tends rather to give up silicon to the combined attraction of carbon and iron; and, in short, that the chemical action which will occur in any given case is governed by the relative masses of the reacting substances in juxtaposition, and the laws of chemical equilibrium. That it may be known where the responsibility lies, it is fair to state that the conclusions above formulated are those of the reviewer, and are not taken from the paper in question.

Emile Demenge, in a paper upon "The Utilization of Exhaust Steam from Engines Acting Intermittently, by means of Regenerative Steam Accumulators and of Low-Pressure Turbines on the Reteau System," brought up a matter which, in spite of its inordinately complex title, is of general interest to all users of power. The idea of the system is to utilize the large quantities of low-pressure steam which at present escapes to waste from such devourers of steam as the reversing engines in rolling mills, large steam hammers, and other machines acting intermittently, and of such a nature that multiple expansion, etc., to provide economy in the use of steam, is inapplicable. Under these conditions, Mr. Rateau proposes to discharge this intermittent supply of exhaust steam into regenerative steam accumulators, which, by their size, serve as reservoirs for the intermittent supply, furnishing themselves a constant supply of steam at an equalized low pressure, to the steam turbines. The accumulator has heavy trays of cast iron within it, which absorb the latent heat of vaporization of any steam coming in above the average pressure in the accumulator, and give out that heat in converting water into steam, if the steam pressure in the accumulator tends to fall. The accumulator thus serves as a reservoir of heat and an equalizer of pressures, and furnishes a steady supply of low-pressure steam, although receiving intermittent supplies of relatively high-pressure exhaust steam. In what is called a "compound accumulator," water is contained in tubes, and thus increases the thermal capacity of the accumulator as a "heat fly-wheel." With the steam turbines it is found that they furnish excellent results at low pressures, in fact, efficiencies of 65 to 75 per cent of the power theoretically obtainable, when exapnding from atmospheric pressure to that of the condenser, while piston engines would yield only 35 to 40 per cent. In fact, the turbines work most economically on low pressures, and piston engines

on high pressures, so that the two supplement each other exactly.

HENRY HUSE CAMPBELL, of Steelton, Pa., general manager of the Pennsylvania Steel Co., and author of his well-known treatise on the manufacture of structural steel, discussed the much debated question of the influence of carbon, phosphorus, manganese and sulphur on the strength of open-hearth steel. The formulæ formerly worked out so carefully by the speaker, whereby the strength of acid steel is 38,600 pounds, increased 1210 pounds for each 0.01 per cent of carbon and 890 pounds for each 0.01 per cent of phosphorus, and for basic steel 37,430 pounds increased 950, 1050 and 85 pounds for each 0.01 per cent of carbon, phosphorus and manganese present respectively (Campbells "Manufacture and Properties of Iron and Steel," pages 482-528), have been found of the utmost practical importance, having been applied to every heat of steel made at the speakers works for the last ten years, with differences usually much less than 1,500 pounds between the calculated and actually-obtained strengths, and seldom attaining 2500 pounds. To check the formulæ, a new investigation was made, including data from nearly 700 heats of acid steel and 110 heats of basic steel. Three bars were pulled from each heat on two different machines, and chemical analyses were made by different methods, that for carbon by three schemes.

The revised formulæ differ from the previous ones mainly in assigning a variable value to the influence of manganese, whose effect is now found to vary with the amount of carbon present. For acid steel the formula for the ultimate strength, in pounds per square inch, is 40,000 + 1000 times each 0.01 per cent carbon, plus 1,000 times each 0.01 per cent phosphorus, plus a value for manganese varying from 160 to 9600 pounds, according as the carbon lies between 0.10 and 0.60 per cent, and the manganese 0.40 to 0.60 per cent. For basic steel the corresponding values are 41,500 pounds to start with, increased 770 pounds for each 0.01 per cent of carbon, 1000 pounds for each 0.01 per cent of phosphorus, and from 550 to 7500 pounds for the manganese, depending on its amount and the carbon conent. Tables are given for the manganese correction, for different values of carbon and manganese. It appears to the reviewer, that the manganese correction might have been expressed numerically as a function of the carbon and manganese, and then the carbon function merged into the carbon factor, leaving the manganese with a single factor, and so simplifying the formulæ. However, as they stand, the research and its results are of a monumental character, creditable alike to the American metallurgist who made them, and to the firm whose liberality and far-sightedness made the work possible, and of value to the whole metallurgical world.

A committee of analysts, JÜPTNER, of Austria, BLAIR in the United States, DILLNER, in Sweden, and STEAD, of England, reported on a "Comparison of Methods for the Determination of Carbon and Phosphorus in Steel." The net result of the investigation showed satisfactory concordance as regards the determinations of carbon, but relatively large variations in the phosphorus. Expressing the latter in thousandths of one per cent, the amounts found in one sample varied from 78 to 102, a tremendous variation, considering that the analyses were made under test conditions. If the variations were possibly due to variations in the samples, then the whole investigation loses its value; if due to errors in the analyses, then the latter certainly need an increase in precision.

J. M. GLEDHILL *discussed* "The Develpment and Use of High-Speed Tool Steel," and exhibited a splendid collection of samples for the works of Whitworth and Co. The paper was a triumphant exposition of the revolution in machining which the high-speed tool has effected, and the statement is made that these steels have not been obtained "without exhaustive scientific research." As constituents of these steels, it is found that the greatest efficiency is obtained with carbon 0.4 to 0.9 per cent, chromium 1 to 6 per cent, tungsten 9 to 16 per cent, silicon not over 3 per cent, molybdenum not yet determined. One of the best Whitworth rapid steels contains 0.55 per cent carbon, 3.5 chromium and 13.5 tungsten. In the discussion, the fact was developed that hundreds of tons of ferro-molybdenum have been used in making American high-speed steels, from 3 up to 10 per cent being used. The electrometallurgist must feel a particular interest in these steels, and share in some degree in the satisfaction which their use is giving, when he sees that the particular ingredients which give the steels their value are mainly electric furnace products, and the general use of these steels binds tighter the bonds between the electrochemist and the greatest modern metallurgical industry. An electrical method of heat and hardening the tools, described by Mr. Gledhill, consisted in using the tool as cathode in a miniature Burton water-pail forge, the heating and quenching temperatures being thus under perfect control.

Probably the most important paper presented at the meeting was by JAMES GAYLEY, the well-known blast-furnace manager, and vice-president of the United States Steel Corporation on "The Application of Dry-Air Blast to the Manufacture of Iron." Enough has been written on the theory of this subject for a generation, but Mr. Gayley directed the expenditure of several thousand dollars in actually trying the matter at the Isabella furnace of the Carnegie Steel Co., and was able to present to the world for the first time a record of results actually accomplished. The blast was dried by being drawn through a chamber artificially cooled by a liquid ammonia refrigerating system; and 90 per cent of its moisture was thus frozen out. The refrigerating machinery consumed 535 hp. The blowing engines were slowed down from 110 to 89 revolutions per minute, to correspond with the coldness of the air drawn in, and the power thus saved was greater than the expenditure for the cooling plant. The average amount of coke used in the furnace per ton of pig iron made was cut down from 2147 pounds to 1726 pounds, a decrease of 20 per cent, while the output of the furnace per day increased from 358 to 447 tons, a gain of 25 per cent. Besides these enormous advantages, the furnace with dried blast worked more uniformly, being practically unaffected by sudden variations in the weather, and producing a regular output of uniform composition, whereas furnaces alongside, with ordinary blast, showed sharp irregularities. The net results are such that it may be predicted that the dried blast will become a regular part of the equipment of all modern blast furnaces.

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

BY GEORGE P. SCHOLL, PH. D.

ELECTRIC FURNACES AND FURNACE PRODUCTS.

Electric Furnace.—Henri Harmet, St. Etienne, France. Patent 772,354, October 18, 1904. Application filed March 20, 1902.

The furnace, which is intended to serve for the direct conversion of iron ores into iron or steel, is shown in cross-section in Fig. 1. This section is taken at right angles to the one given in ELECTROCHEMICAL INDUSTRY, vol. I., page 422, and shows the upper part of the apparatus more in detail. The four steps of the conversion, namely, the calcination, the reduction,

the fusion of the reduced metal, and the refining are carried out in three vessels, only two of which are shown in the figure. The ore is introduced into the calciner *d*, mixed with the necessary fluxes, but without addition of coke. The shape of the calciner in its upper part is that of an inverted cone. The lower part is contracted for a certain distance, and then widens out considerably. This peculiar shape is stated to secure the proper calcination of the charge by the time it arrives on the sole 4, inasmuch as the top of the chamber 1 being wider than its base 3, allows of the materials to be slowly heated in order to properly dry them. The contracted part 3 subjects the materials to a concentrated heat, and the enlarged chamber 1*a* provides for a space 10 above the sloping sides of the materials for the circulation and proper combustion of the gases fed in through pipes 2. The charge arrives on the bottom of the calciner at a red heat, with all water of combination, volatile matters and carbonic acid driven off. It then is pushed by a piston, not shown in the figure, at regular intervals into the passages 6 and 7, which lead it to the chargers 8 and 9. The lower part of the calciner is made completely air-tight, so that the gases delivered by the pipes 2 are forced to travel upwards through the materials contained in the calciner. The reducing apparatus *e* is fed alternately from one or the other of the chargers with ore in a red-hot condition, and in order to have the reducing carbon, preferably coke, also highly heated, provision is made for a heating vessel 17 of refractory material, into which a portion of the hot gas from the top of the reducer is introduced. The hot ore, flux and coke then travel downwards in the reducer *e* and are reduced in their passage by the carbon of the charge, aided by a portion of the gases collecting at the top of the reducer, which are rich in carbon monoxide. A suitable quantity of them is drawn off through pipe 21 by an exhaust fan 22 and blown at high pressure through pipe 23 and tuyeres 24 and 25 into the fusion zone of the apparatus, a little above the level of the slag. This procedure is stated to be very important, in order to be sure that the ore is completely reduced before the zone of fusion is reached. The reduced charge is then melted in the crucible 25, by means of a series of electrodes, not shown in the figure, which are arranged at equidistant points around the circumference of the crucible 25, and are preferably introduced through the top wall of the crucible, so as to be as nearly vertical as possible. The electrodes only dip into the slag 28, the electric heating being done entirely by resistance, and as they should constantly dip into the slag, the variations in the height of the latter must be very small. They should also be only a small distance away from the base of the crucible, and the latter is therefore constructed bell-shaped, with a very flat arch *a*. The increasing diameter of the crucible is necessitated by the requirement of accommodating a sufficiently large number of electrodes to transmit the heavy currents used in the operation. The slag is drawn off through a Lürmann tap and the metal goes into a refining vessel. The latter

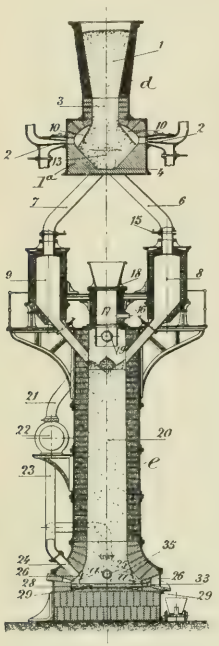


FIG. 1.—IRON REDUCTION FURNACE.

ranged on the inside of the kiln wall, which flue conducts the consists essentially of a chamber of circular horizontal cross-section, and provided with a charging door and tapping holes for the slag and metal respectively. It is not movable, in order to keep the bath as quiet as possible, and to prevent it from mixing with the slag. It is heated by carbon electrodes, which pass either through the top or the walls. The subject of the economic reduction of iron and steel directly from the ore is one which admits of much discussion and has been thoroughly ventilated in the pages of Electrochemical Industry. Whether the above apparatus might be a commercial success, is hard to decide; there is that much in its favor, that the inventor, Mr. Harmet, is a practical metallurgist of long experience and presumably well acquainted with the manufacture of iron and steel.

Electric Furnace.—C. P. Steinmetz, Schenectady, N. Y., assignor to General Electric Company. Patent 773,821, November 1, 1904. Application filed May 24, 1900.

The furnace is intended for the production of temperatures ranging between those ordinarily obtained by combustion, and that of the electric arc. Its action depends upon the fact that many refractory materials, such as refractory oxides, silicates, tungstates, chromates, etc., while showing a high resistance at ordinary temperature, become conducting when heated, the conductivity increasing with the temperature. The furnace illustrated in the specification is of simple construction, and consists of a block of refractory material having the above characteristics. It is hollowed out so as to form a receptacle for the &substance to be acted upon. The terminals for conducting the current into the furnace are cone-shaped pieces of carbon, which are inserted into openings provided in the refractory material at opposite ends of the furnace, and project somewhat into the central cavity. The refractory material between the electrodes has to be heated up, of course, before a current can flow, and while external heat may be applied to the furnace for this purpose, it is preferred to do it by means of a small rod or filament of carbon arranged between the terminals and embedded within a recess in the bottom of the central cavity. The temperature is regulated by varying the electromotive force impressed upon the furnace by any suitable means, such as division of the primary of a transformer, the secondary of which is connected to the furnace. Owing to the potential gradient or drop in voltage along the heated space being of the magnitude of 1000 volts per inch, as compared to, say, 10 volts per inch in the carbide furnace, it is possible to expend a large amount of energy in a comparatively small space, and thus to produce extremely high temperatures, and to accomplish the desired chemical reactions. Mr. Steinmetz states that he has found by experiment that by heating aluminium silicate by this means, it fuses to a transparent mass, colored yellowish by impurities and of the nature, hardness and composition of topaz. He has also succeeded by small traces of chromic oxide and cobaltic oxide in obtaining green and blue transparent masses of the nature of emerald and sapphire, and in other cases he produced a red color.

Electric Kiln.—F. E. Dickinson, Kendallville, Ind. Patent 773,853, November 1, 1904. Application filed January 12, 1903.

The object in the construction of this furnace has been to overcome the heat losses in kilns such as used for the manufacture of brick, pottery, etc., by reason of the intake of cold air required to maintain combustion and the injurious effect upon the wares, such as pottery, etc., by the admission of cold air into the treating chamber. The kiln consists essentially of a round masonry construction with arched dome. Around its lower part are distributed at equal distances a series of rectangular, radial heating chambers, tightly closed and roofed over. One or more pairs of carbons are introduced air-tight through openings in the opposite side walls of the heating chambers and the arcs are struck between them. Each of the heat chambers opens into an upright flue ar-

air heated by the arcs to the roof of the kiln, whence it descends on the articles to be heated. A perforated false bottom is provided in the kiln, which communicates with a series of passages by which the partially cooled air is reconduced into the treating chambers in close proximity to the arcs, to be heated again and to re-enter into circulation as described above. A central opening in the dome permits the escape of moisture given off in the beginning of the operation of the green wares and permits a limited ventilation whenever desired. It is claimed that on account of the continuous circulation of the heated air only a slight reheating is required to compensate for the loss of heat by radiation from the walls of the kiln, and an economy in fuel and labor is effected.

ELECTROLYTIC PRODUCTION OF METALS AND COMPOUNDS.

Manufacture of Cellulose.—Carl Kellner, Vienna, Austria. Patent 773,941, November 1, 1904. Application filed March 18, 1903.

The process aims at the utilization of the chlorine produced in the electrolysis of alkali or metallic chlorides. The portions of plants from which the cellulose is to be produced are first treated with water or preferably with milk of lime or a very weak solution of an alkaline carbonate or hydroxide. After the excess of liquid has been removed by suitable means, the portions of plants under treatment are subjected to the action of electrolytic chlorine, which causes the incrusting substances (lignines) to be oxidized and to be converted into substances completely soluble in very weak alkaline liquids, and in many cases completely soluble in hot water. Care has to be taken that the materials are promptly removed from the chlorinating vessel as soon as they are permeated by the chlorine, since otherwise the cellulose would be converted into oxycellulose and chlorinated in various stages, whereby the product would become very brittle and of very little value. After the chlorination the materials are treated with water, and if any portion of the chlorinated incrusting substances still remains insoluble in the water, they are treated with a very weak solution of milk of lime or caustic alkali or alkali carbonate. The residue, which consists of nearly pure cellulose, is well washed with water and bleached if desired, and is then dried and placed on the market. Mr. Kellner states that one hundred parts, by weight, of air dried pine-wood requires ten parts, by weight of lime, or 0.15 parts by weight of caustic soda, absorbs thirty-two parts by weight of chlorine, and requires for the second bath twenty parts by weight of lime, or 0.30 parts by weight of caustic soda, loses in the first bath 0.4 parts by weight of its weight and produces fifty parts by weight of cellulose. One hundred parts by weight of esparto requires twenty parts by weight of lime, or 1.5 parts by weight of caustic soda, absorbs 15 parts by weight of chlorine, and requires for the second bath twenty parts by weight of lime or three parts by weight of caustic soda, loses in the first bath 1.2 parts by weight of its weight, and produces fifty-five parts by weight of cellulose. As only a small amount of alkali hydroxide or carbonate is required for the treatment of the cellulose containing substances, it is obvious that the larger portion of the alkali produced in the electrolysis of the alkali chloride can be removed as such and placed on the market, while the entire amount of the chlorine is utilized to a better advantage than in the production of bleaching powder.

Electrolytic Apparatus.—A. Brichaux, Brussels, Belgium, Assignor to the Solvay Process Co., Syracuse. Patent 774,230, November 8, 1904. Application filed October 4, 1898.

The apparatus, illustrated in cross-section in Fig. 2, is evidently intended for the electrolysis of alkali chloride, with a mercury cathode. It comprises a receptacle A for the electrolyte, with a mercury cathode a^2 on the bottom and a series of conductors a^3 as anodes. The principal object in the construction has been to provide for the establishment and the maintenance in the electrolyte of two layers of unequal density, a heavier one *a*, and a lighter one *a'*. The formation of these layers is brought about by means of the partitions B, B, B', B', which may be fixed, but are generally movable up and down, and may be adjusted by means of the nuts *b b'*. The vessels *C C'* contain the material to be electrolyzed, and are generally of unequal size. The heavier electrolyte enters into the

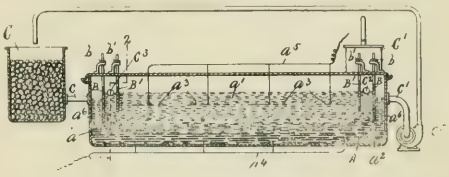


FIG. 2.—ELECTROLYSIS OF ALKALI CHLORIDE.

receptacle A by means of pipe *c*, from vessel C, and at the opposite end of the apparatus is removed through pipe *c'* into a pump or suction device c^6, whence it returns to the vessel C, thus keeping up the circulation. The lighter layer of liquid *a'* circulates in a similar manner by means of pipes c^2 and c^5 and vessel C'. In the operation of the apparatus the lower layer of liquid is almost or entirely saturated with the material to be electrolyzed, *f. i.*, alkali chloride, while the upper layer contains a lesser amount. It is claimed that the dense lower layer serves the purpose of a diaphragm without the inconveniences attendant upon the use of a solid diaphragm. It is stated to remain practically free from the substances, such as chlorine, which are liberated at the anode, inasmuch as it is saturated with the material to be electrolyzed, such as alkali chloride, and that as it is maintained in circulation as a distinct layer it does not perceptibly mix with the upper layer of lesser density. No provision is shown for discharging the amalgam, in order to liberate the sodium which it takes up during electrolysis, and presumably this operation takes place in a separate vessel, after which the mercury is again returned to the electrolyzing vessel.

STORAGE BATTERIES.

Storage Battery.—C. B. Morgan, Cleveland. Patent 773,961, November 1, 1904. Application filed April 18, 1904.

The invention aims at providing a light portable battery, especially for automobiles. For this purpose the inventor provides a plate furnished on the inside with a series of pockets formed by vertical and cross-ribs, two of such plates being soldered together. The plate is cast of aluminium and then electroplated with nickel or other relatively cheap conducting metal which is not attacked by the electrolyte. The pockets are then filled with aluminium cubes, balls, squares, granules or other pieces, which are also electroplated. With these pieces such active material is incorporated as is needed to completely fill the interstices. The outer surface of the plate is provided with numerous fine perforations for the purpose of circulation.

Process of Electrolytically Producing Lead Peroxide Layers Upon Positive Accumulator Plates.—J. Diamant, Raab, Austria-Hungary. Patent 774,049, November 1, 1904. Application filed January 4, 1904.

The process relates to the acceleration of the formation of layers of peroxide of lead upon the surface of the battery plates. For this purpose there is added to the electrolyte a sulphonic or oxysulphonic acid derivative of methane, and of its hydroxyl substitution products, such as methyl-sulphonic acid, methylene disulphonic acid, methylidene trisulphonic acid, oxymethylenesulphonic acid and oxymethylidene sulphonic acid. The derivatives of oxysulphonic acid are derivatives of the oxymethylene sulphonic acid, and of the oxymethylidene disulphonic acid, $CH_2(OH)(HSO_3)$ and CH-

$(OH)(HSO_3)_2$, respectively. Sulphonic acids of this kind are obtained usually as mixtures by the action of sulphuric acid or sulphuric anhydride or fuming sulphuric acid upon organic compounds having a methyl group, which is easily split off, for instance, methyl alcohol, methyl sulphuric acid, ethyl alcohol, acetaldehyde, acetic acid, or the like. The different sulphonic or oxysulphonic acids may either be separated from each other by taking advantage of the different solubilities of their salts, and added in a pure form to the electrolyte used for forming the plate or the mixture may be added as such. During the electrolytic process the above substances will furnish only sulphuric acid and carbonic acid, neutral in their action upon the formed accumulator plate.

Storage Battery.—E. A. Sperry, Cleveland. Patent 773,686, November 1, 1904. Application filed February 11, 1904.

The invention relates specifically to large batteries such as are used in central stations, and has for its object the diminution of the thickness of the walls of the containing vessels, and the doing away with the rigid connections which render it difficult and expensive to remove any electrode for inspection or renewal. The construction, as shown in Fig. 3,

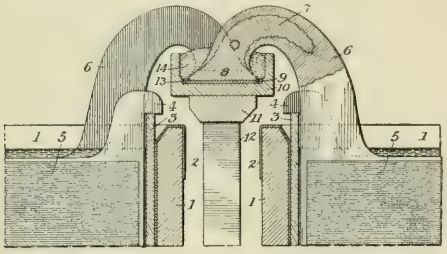


FIG. 3.—STORAGE BATTERY CONSTRUCTION.

comprises a containing vessel 1, with comparatively light walls and a lead lining 2. A vertical glass plate 3 at each end of the vessel serves as support for one end of the plates by means of the lug 4. The other end of the electrode has a terminal lug 6, which curves upwards over the end of the vessel and then downwards again. The lug has a flat face and rests directly on a copper plate 9, which is supported on the flat bottom of the trough 10. The shank 7 of a contact piece 8 of iron is cast into the lug 6, serving both to stiffen it and to increase its conductivity, and, moreover, making it possible to decrease the contact resistance between the contact piece and the copper plate by amalgamation. A layer 13 of mercury is placed in the trough 10 for this purpose, covering the contact surfaces. In order to exclude acid fumes, the rest of the trough is filled with plastic insulating material, preferably vaseline. The trough 10, of insulating material, such as vulcanized fiber or wood, rests on a wooden beam 11, which in turn is carried by posts 12. By this arrangement the walls of the containing vessel are relieved of one-half of the weight of the electrodes, thus making it possible to choose thinner and less expensive vessels, while the removal of any electrode can be readily effected.

Storage Battery Electrode and Process of Making Same.—E. A. Sperry, Cleveland. Patent 773,685. November 1, 1904. Application filed January 28, 1904.

The object of the invention is to produce a highly porous active material, preferably consisting of nearly equal parts of litharge and minium, and to provide the body or bodies of porous active material carried by the grid with relatively large feeder pores for the electrolyte. For this purpose a carbonate of lead is first chemically precipitated from a soludition of a lead salt, which carbonate may be the normal carbonate $PbCO_3$ or any of the basic carbonates, but preferably the basic carbonate known as white lead. The carbonate may be precipitated from an aqueous solution of any soluble lead salt, such as the acetate or nitrate, but it is preferably produced by electrolyzing an aqueous solution of sodium acetate, using a lead anode, and continuously introducing carbonic acid into the electrolyte. The pure precipitated lead carbonate, which is very finely divided, is then roasted to expel the carbonic acid, the roasting being by preference carried to such a point as to produce a porous mixture containing 10 parts of litharge and 12 parts of minium. The porous oxides may be directly applied to the battery grid or support, but it is preferred to add a salt which can be readily dissolved out by placing the electrode in water, also a salt which is capable of partially combining with and hardening lead oxides. Ammonium sulphate is preferably employed for this purpose, from 5 to 10 per cent being mixed with the material and the mixture then applied to the grid or support and pasted or press-welded into place. The electrode is then placed in water, by which the greater part of the ammonium sulphate is dissolved out, thus leaving large feeder pores for the electrolyte. The plate is then formed by any usual process.

Galvanic Elements.

Electric Battery.—T. L. Roberts, New York. Patent 771,498, October 4, 1904. Application filed October 14, 1903.

The battery belongs to the type of dry cells, and consists of a containing jar of wood, which contains two wooden frames of suitable size, the sides of which are covered by sheets of cloth, and which are filled with a mass of conducting and depolarizing material. The latter is in the form of a paste of powdered carbon and manganese peroxide, moistened with a solution of zinc chloride. Carbon rods, serving as one electrode, pass through this paste. The positive electrode, a sheet of zinc covered on both sides with a liquid-absorbing medium, such as blotting paper or wood pulp, moistened with a solution of zinc chloride, is placed between the two frames. A little pan with water, into which the absorbent covering of the zinc dips, may be provided for the purpose of keeping the covering moist by capillary attraction. The air is allowed to permeate freely through the depolarizing mass and to restore to the latter the oxygen consumed during the action of the cell.

Battery Holder.—F. Jackson, Denver. Patent 772,415, October 18, 1904. Application filed March 4, 1904.

The invention is to be used in connection with dry batteries for producing sparks in gasoline or other vapor-operated connecting and disconnecting wires when replacing a spent battery with a fresh one, and at the same time to provide for securely holding the batteries in place. A mechanical construction embodying these points is described and illustrated in detail. It consists essentially of a box with a series of compartments, each of which is provided with a metal casing designed to partially enclose and tightly hold an ordinary dry battery. Conductors extend from the casing of one battery to the top of the adjoining compartment, and contact is made with the carbon tops of each cell by means of a contact plate, which is pressed against the carbon by a spring.

Medical Battery.—L. W. Pullen, Philadelphia. Patent 772,959, October 25, 1904. Application filed February 18, 1904.

The battery consists of a core of insulating material, such as wood, having lateral projections, one of which is longer than the other. The shorter one fits into a tube which also contains a galvanic cell, and suitable provision is made for connecting it with an induction apparatus which is located within the other longer end of the core. A tube is also fitted over the end which carries the induction coil, and provision is made for adjusting the tube longitudinally for the purpose of regulating the strength of the secondary current.

Clamp for Battery Electrodes.—E. G. Dodge, Orange, N. J. Patent 773,249, October 25, 1904. Application filed June 27, 1904.

The clamp is adapted for batteries of the type in which the

negative plate consists of molded copper oxide or other oxide, and provides for securely holding and locking them and preventing their accidental detachment.

Electric Battery.—C. F. Mackey, Philadelphia. Patent 773,331, October 25, 1904. Application filed December 11, 1903.

The inventor claims in an electric battery a zinc positive element forming a casing with a perforated wall, flanges at its upper end forming support hooks, a carbon negative element in the casing, a receptacle to which the casing is fitted, the flanges of said casing engaging the edge of the receptacle and an electrolyte in the receptacle.

MISCELLANEOUS.

Process of Electrically Treating Gases.—K. Birkeland, Chrisania, Norway. Patent 772,862, October 18, 1904. Application filed June 15, 1903, divided and refiled April 2, 1904.

The process described in the specification is specially intended for the treatment of air for the purpose of producing nitrogen compounds from the atmospheric nitrogen. It has formed the basis of a paper read by Edstrom before the Electrochemical Section of the recent International Electrical Congress at St. Louis, an abstract of which is given in ELECTROCHEMCAL INDUSTRY, vol. II., page 399. In principle it is based upon the fact that electric arcs produced between electrodes situated within a magnetic field may be dispersed or spread out by the action of the magnets. An arc or high or low tension may thus be spread out into a disc or sheet having a volume several hundred times as large as the original arc. The main features of an apparatus working on the above principle are diagrammatically illustrated in the adjoining Fig. 4 in perspective view. In this figure M represents the electromagnet, one pole of which is broken away so as to afford a better view of the arrangement. The electrodes C C′, between which the arc is struck, are enclosed in a housing S of fireproof material, the air inlet being at T and the outlet at U. With a suitable distance between the electrodes and a suitable current, as well as a suitable magnetism, there will be produced a dispersed arc, indicated by the curves *a*, which arc is in the shape of a permanent sheet or disc at right angles to the lines of force of the magnetic field. If currents of high voltage, *f. i.*, 5000 volts are used, it has been found suitable to place the electrodes at a fixed distance of some millimeters apart. The air coming in at T therefore passes through the flame in the direction of its plane, and is thus exposed to an energetic action of comparatively long duration. An alternative form of the apparatus shows a circular electromagnet between the poles of which is placed a tubular housing, which is divided into a series of vertical channels by means of partitions alternately extending to the top and the bottom plates. A zig-zag channel is thus formed through which the air is passed. In each of the compartments thus formed a pair of electrodes is placed. It is claimed in the above-mentioned paper that with this process an efficiency of 900 kilograms of 100 per cent nitric acid per kilowatt-year as compared with published results of 700 kilograms per kilowatt-year, according to the Bradley and Lovejoy system, and 580 kilograms per kilowatt-year in the method employed by Kowalski and Moscicki has been obtained.

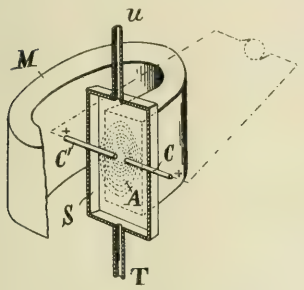


FIG. 4.—FIXATION OF ATMOSPHERIC NITROGEN

Process of Removing Water from Peat.—B. Kittler, Memel, Germany. Patent 772,891, October 18, 1904. Application filed March 19, 1904, divided and refiled June 17, 1904.

Apparatus for Removing Water from Peat.—B. Kittler, Memel, Germany. Patent 772,717, October 18, 1904. Application filed March 19, 1904.

The process depends upon the treatment of peat simultaneously by the action of heated gases, and an electric current, the process being further aided by the establishment of a partial vacuum in the treating chamber of the apparatus, thus providing an active circulation of the heated air. The apparatus consists of a cylindrical outer vessel, inside of which is arranged another cylinder with its walls parallel to the first one, but located so that an annular chamber is formed between it and the outer vessel. An insulating cover and bottom are provided. A central hollow shaft is arranged within the apparatus, which carries a series of helically arranged arms. The latter are also hollow, and each of them forms a sort of trough, covered with a strainer, through which the heated air passes into the inside of the apparatus. The shaft is rotated and is in connection with the positive pole of the source of current. The above mentioned inner cylindrical vessel, which is perforated in order to act as a strainer, is connected to the negative electrode. A charging pipe in the top, and a discharging pipe in the bottom of the apparatus are also provided. The operation of the apparatus consists in filling it with peat and setting the agitating arms into rotation. The hollow shaft is then connected with the supply of hot air, and the vacuum pump started. The hot air will then pass through the peat, while the electric current passes out at the agitator arms and travels towards the inner straining vessel. It is claimed that every particle of the peat is thus acted upon, while the partial vacuum will cause a constant discharge of water into the annular chamber mentioned above, whence it is removed by the pump. The helical arrangement of the agitator arms causes the peat to descend, so that a compact mass of dried peat accumulates on the bottom and is withdrawn through the discharge pipe at desired intervals.

Apparatus for the Electrical Treatment of Air.—J. E. Mitchell and D. Parks, St. Louis. Patent 773,407, October 25, 1904. Application filed July 9, 1904.

The apparatus comprises an air pump, and two upright air tubes. In the bottom of each of the latter there is provided a stationary electrode, while a movable electrode is introduced through the top. By means of suitable mechanism, shown in detail, these movable electrodes are alternately raised and lowered, and an arc is thus struck and extinguished between them and the stationary electrodes. The mechanism is so arranged and connected with the motion of the air pump, that the latter draws the air alternately through the two air tubes, and that simultaneously with the movement of the air through the tubes the electrodes are drawn apart, thus causing an electrical discharge and insuring that all the air drawn into the pump is subjected to the action of the discharge.

RECENT METALLURGICAL PATENTS.

IRON AND STEEL.

T. J. Tresidder (U. S. Patent 774,958, November 15) patents a steel containing iron and carbon, manganese, nickel and tungsten in about the following proportions: Carbon, 0.28 to 0.32 per cent; managanese, 0.25 to 0.30 per cent; nickel, 2.25 to 2.50 per cent; and tungsten, 0.28 to 0.32 per cent, the remainder being iron. Such steel, while readily perceptive of a fibrous structure under suitable treatment is claimed to

retain that fibrous structure under conditions that would ordinarily produce a crystalline structure, such, in particular, as the sudden chilling from a very high temperature necessary in the process of face-hardening after supercarburization.

M. P. Boss (774,304, November 8) patents a method for converting iron ore into steel continuously within a single furnace structure. The method consists essentially in subjecting the ore to the reducing action of a hydrocarbon flame and at the same time to the combining action of a hydrocarbon vapor. The process depends, therefore, "upon the observed fact that in a furnace heated by a hydrocarbon fuel a hydrocarbon vapor may exist which is not consumed, but will combine with a heated metal when the two are brought in contact." The furnace consists of an inclined chamber, the lower end of which connects with a horizontal chamber. The ore is fed into the furnace at the top of the inclined chamber. Located under the hopper, and so situated as to direct a flame of gas and air in a downward direction along the inclined chamber, are gas and air burners; any suitable gas and air burners may be used, or burners adapted to operate with a hydrocarbon oil or a producer gas. Located directly under the burners are a series of pushing-screws through which oil pipes pass. These screws push the ore downward along the inclined hearth while simultaneously a certain amount of oil is fed into the ore body. During the passage of the ore downward, it comes in contact with the hydrocarbon vapor from the fuel thus introduced. "This vapor combines with the iron ore under treatment with the result that steel having the required proportion of carbon is directly produced."

W. E. Everette (774,167, November 8) patents a process of direct casting and hardening of metal for armour plates, tool metal, rails, etc. The process may be applied either to pig metal or to the raw ore, and dispenses with the necessity of having to Bessemerize the molten metal. The chief feature is the use of a cyanide as flux. The cyanides employed are preferably the cyanide of calcium (which is the cheapest), the cyanide of soda, and the cyanide of potash. The slag thus produced is valuable as a fertilizer. The operation is as follows: A quantity of pig metal or raw ore is placed in a suitable furnace with the proportionate quantity of flux and heated to about 2800° F. Both the pig metal and raw ore have been previously finely crushed, and the quantities to be used are 60 per cent of pig or ore and 40 per cent of flux. The composition of the flux differs slightly for the ore and for the pig metal. For each the flux consists, preferably, of ⅛ iron oxide, ⅛ metallic aluminium, ⅛ alkaline nitrate, and the remaining ⅝ carbon and alkaline cyanide. For pig metal two of these five-eighths are cyanide, while for raw ore only one-eight is cyanide. All of these ingredients are pulverized and well mixed. Fusion is rapid at the stated temperature. When the molten mass in the furnace is ready to pour, the inventor injects into it while still in the furnace, by suitable pressure, a boiling liquid composed of a quantity of molten cyanide of the desired alkali equal to 5 per cent of the charge in the furnace, to which have been added puverized sulphide of molybdenum, pulverized metallic chromium, manganese, and aluminium in varying quantities, depending upon the purpose for which the metal is to be used. As soon as the high fusion caused by this mixture takes place, the molten mass is drawn off into suitable molds of carbon-lined silica sand. If the material is to be used as a direct casting, it is cooled down to low red heat, about 1000° F., and after scratching the surface of the hot metal free from carbon, dirt, sand and adhering impurities, the incandescent metal is subjected to a spray of intensely cold liquid carbonic acid.

H. B. Atha (774,973, November 15) patents a method for recarburizing scrap steel, containing a small amount of carbon, and for producing thereform a high-grade commercial steel. This scrap is treated with carbon, but to prevent the latter from being driven off before it is absorbed by the scrap, the inventor places finely divided carbon into small sacks and mixes these sacks throughout the scrap steel, and presses the two into bundles formed into tubes of about 2 feet in dimension. The bundles so prepared are treated in an open-hearthed furnace.

W. B. Burrow (775,026, November 15) patents a mechanical puddling furnace intended to cheapen and quicken the process of puddling and refining iron. The furnace is so constructed that when molten cast iron is placed in the movable hearth, it is given a horizontal movement back and forth on inclined planes or sloping bases forming a part of the bridge-walls. The rapid rise of the oscillating hearth at each end of the furnace and by its sudden stoppage causes the metal to run down the inclined hearth to the opposite end of the same, and is abruptly arrested and dashed against the lining. This action is repeated any number of times, until the iron is brought to the desired condition suitable to be rolled and worked. The sudden and frequent stoppages, and consequently the undulating motion of the iron, exposes it perfectly to the action of the heated gases. The metal as it parts from its carbon becomes finally consolidated into a ball, which is removed to be worked in the usual manner. The operation is assisted by a hollow-toothed combing-bar or rabble extending across the furnace in the direction of its width, which combs or rakes the metal as it passes backward and forward and also prevents the fluid from dashing too violently against the lining, besides acting as a mixing tool. The toothed bar is used at the beginning of the process when the metal is fluid and is withdrawn as the metal thickens.

Nickel.

R. R. Maffett (774,591, November 8) patents a furnace for reducing and smelting nickel oxides. The oxide is treated in two successive steps: First, roasting of the oxide in admixture with carbon, by which the oxide is reduced partially to metal, and, second, smelting of the oxide and metal on the hearth of a smelting-chamber, by which the reduction is completed; the metallic nickel is withdrawn from the smelting-chamber and cast into molds. Both these operations are carried on in a single furnace with a great saving of fuel and labor. The furnace has an open-hearth smelting-chamber, an elongated reducing-chamber leading therefrom, charging-openings for the reducing-chamber arranged lengthwise thereof, a flue extending beneath the reducing-chamber, and a stack-flue with which the reducing-chamber and flue commnicate at their rear ends. The flame from the burners feeding the charge in the smelting chamber passes under the reducing chamber and heats the charge therein to incandescence until it is sufficiently reduced.

Aluminium Alloy.

R. S. Anderson (773,450, October 25) patents an alloy designed for commercial use wherever ductility is desired in conjunction with lightness and also for use as an anti-friction metal and as a good conductor of electricity. Ninety-three parts by weight of copper and seven parts of tin are heated in a crucible; when fluid two parts of pulverized copper-sulphate are added. The melted mass is poured off into mats or pigs and cooled for subsequent use with aluminium. The proportion of aluminium for general use is two pounds of aluminium to five ounces of the alloy of copper, tin and copper sulphate.

Various Furnace Designs.

A. P. O'Brien (775,147, November 15) patents mechanical details of construction of the well-known general type of roasting furnaces containing a series of floors of brick with charge openings in each floor to the next one below, the discharge openings being alternately at the circumference, and at the center of the floors, while a central shaft carries rabbles for stirring the ores upon the floors so as to move them

from one floor to the other. This patent refers to various mechanical details of construction.

H. Cockell and W. H. Fish (772,925, October 25) patent a roasting and smelting furnace as shown in Fig 1, the lower left-hand figure being a sectional view of the furnace on the

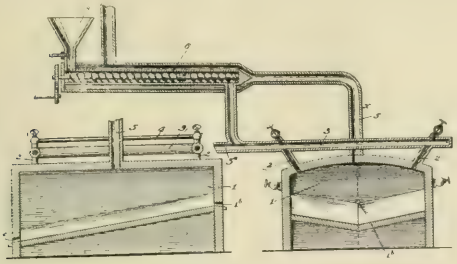


FIG. 1.—FURNACE DESIGN.

plane indicated by the line *xx* in the right-hand figure. 1 is the furnace, which has an inclined trough-like bottom, with a tap 1b to discharge the slag and the top 1c to discharge the metal. Connected with the fuel and ore-inlets 2 are pipes 3, air being supplied through 3a, while 4 are oil or gas pipes, 6 is an ore-feeding and roasting-chamber containing a conveyor. The ore is fed through the hopper 8 into this chamber and then passes through 3 into the furnace. The ore is roasted in 6 by the hot gases escaping through 5 from the furnace, there being no direct connection between 5 and the ore in the roasting chamber.

H. F. Brown (774,930, November 15) patents a process for reducing ore in a stack furnace, as shown in Fig. 2, with the use of hydrocarbon fuel, such as oil or gas, or of powdered charcoal, coke or coal dust. The essential feature is that the ore first passes in a finely divided condition through a high heated, non-whirling atmosphere. The necessary fluxes are added previous to charging the ore. The second step resides in subjecting the particles as they pass beyond the zone of the oxidizing atmosphere to the action of a whirling reducing atmosphere which conveys the ore downward through a reducing zone of the stack within which the ore is being treated. This atmosphere is so regulated that as it passes down the stock of the furnace a vortex is formed which brings the segregated particles together, which vortex also forms and maintains a zone of concentrated heat so that instant combination and fusion takes place. 2 is the combustion chamber, the burners 16 for the oil being so arranged that the flame is given a spiral motion which will follow down the shaft. The zone of reduction within the furnace shaft exists between the points *a* and *b*, while the atmosphere maintained between the vibratory feed-plate 3 and the combustion-chamber 2 is the highly-heated, downwardly-moving, non-whirling atmosphere to the action of which the ore is first subjected during its travel through the stack.

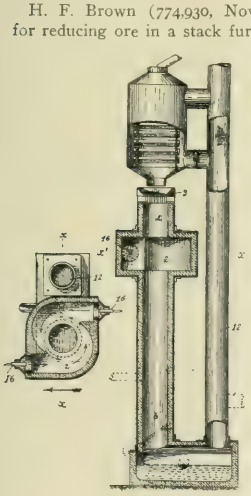


FIG. 2.—REDUCTION FURNACE.

K. Schneider (774,788, November 15) patents details of construction of charging apparatus for blast furnaces. In furnaces with inclined skip-hoists the disadvantage arises that if the hoist gets out of order, the charging can only be effected with the greatest difficulty. The inventor connects the furnace tops of two contiguous furnaces by a conveying device, by means of which the ores and other materials can be conveyed from the mouth of a furnace whose hoist is in working order to a contiguous furnace whose hoist is out of order.

A. C. Calkins (774,232, November 8) patents details of construction of an assayer's furnace containing a crucible chamber and a muffle, for the use of liquid fuel.

CLEANING BLAST FURNACE GASES.

In the utilization of the blast furnace gases for driving gas engines—which is making slow but steady progress in this country—it is most important to remove dust and the like from the gases. A. G. McKee (774,851, November 15) patents apparatus for this purpose. It is essentially a fan which imparts a rapid rotary movement to the gas by which all non-gaseous material, such as coke, ore, etc., is forced outwardly by virtue of the centrifugal force, and drops into a special chute.

Current Notes.

BETTS PROCESS OF LEAD REFINING.—The Canadian Smelting Works in Trail, B. C. (see paper of Mr. A. G. Betts, in our September issue, 1903) are rushing the addition to their old electrolytic lead refinery to make it a fifty-ton plant. They are at present refining over 20 tons a day, with fine results. They are working up part of the lead into lead pipe, and are supplying the Canadian trade with from ¼-inch to 3-inch lead pipe. An interesting new development is that they have contracted for the erection of a white lead plant in Montreal, where Betts electrolytic lead will be corroded. A carload of lead was sent to the Carter white lead works, where a test was made. The results were most satisfactory, as a very high-grade white lead was obtained, a much whiter product than that made from ordinary refined lead.

FARADAY SOCIETY.—The Council of the Faraday Society announces that the society will in future publish its own Transactions, instead of including them in the *Electrochemist and Metallurgist*, which has heretofore been the organ of the society since its inception. The society will issue in future quarterly Transactions, containing in full the papers which have been read before the society and the discussions thereon. In addition there will appear monthly Proceedings, containing reports and notices of meetings, abstracts of the papers read during the previous month, and of the discussions thereon, abstracts of electrochemical patents, and the physical chemistry section from Science Abstracts. All papers will be printed before they are read, and sent in proof form to every member of the society. The first volume of the Transactions will appear about the end of the present year.—The *Electrochemist and Metallurgist* has in the meanwhile suspended publication; the publisher intends to issue, beginning with next year, a monthly publication entitled *Metals*, with which the above-named journal will be incorporated.

NEW PUBLICATION.—The first number of a new journal with the title *The Chemical Engineer*, a monthly journal of practical, applied and analytical chemistry, has just been issued. It is published by the Chemical Engineer Publishing Co., of Allentown, Pa., Mr. Richard K. Meade being the editor. The first issue contains the following articles, among others: Valuation of Coal for Steaming Purposes; Tests for Wood Paving Blacks, by F. A. Kummer; Determination of Lime in Limestone, Cement, Etc., by R. K. Meade; Carbon Combustion Apparatus, by P. W. Shimer; Silica Determinations, by H. E. Ashley; Protection of Structural Work from

Rust, by R. Job; Bismuthate Method for the Determination of Manganese, by A. A. Blair. We wish every success to our new contemporary.

Pyrometry.—The importance which thermodynamical reasoning has assumed in the development of modern physical chemistry, has emphasized the fact that the temperature is a factor of fundamental importance in determining the reaction which goes on between given reagents. The importance of this fact has always been recognized to greater or less extent by practical metallurgists and chemical engineers. The necessity of controlling the temperature required exact methods of measuring it. With the arrival of the electric furnace the temperatures available to the chemist and metallurgist were very considerably raised and the difficulties of temperature measurements were correspondingly increased. Dr. C. W. Waidner, of the National Bureau of Standards, has rendered most useful service to the industries by summing up the more widely used methods of pyrometry in a very lucid and concise way in a paper read before the Engineers' Society of Western Pennsylvania. The paper is printed in the September number, 1904, of the Proceedings of this Society, and has recently been issued in form of a pamphlet of ninety pages. The subject is discussed under the following headings: Expansion pyrometry (solids and gases), specific heat pyrometry, thermo-electric pyrometry, electric resistance pyrometry, optical pyrometry, and transpiration and viscosity pyrometry. In each class the fundamental types of apparatus are described, illustrated and discussed. The bibliography of 133 original papers should be greatly appreciated by those wishing to study the problem to a greater extent.

Refractories.—We have received from Messrs. FitzGerald & Bennie, of Niagara Falls, two interesting samples of a material which they recently turned out from an electric furnace run. The samples are virtually fused magnesia, as the original material was magnesite. They are instructive in showing the effect of very high temperatures on some of the materials which are considered good for ordinary types of furnaces, but which break down with the higher temperatures of the electric furnace.

Book Reviews.

Monographs on Applied Electrochemistry.—Vol. I.: *The Electrolysis of Water,* Processes and Applications. By Victor Engelhardt. Authorized English Translation by Dr. Joseph W. Richards. Easton, Pa.: Chemical Publishing Co. 140 pages, with 90 figures and 15 tables in the text. Price, bound, $1.25. Vol. III.: *The Production of Chromium* and Its Compounds, by the Aid of the Electric Current. By Dr. Max Le Blanc. Authorized English Translation by Dr. Joseph W. Richards. Easton, Pa.: Chemical Publishing Co. 122 pages. Price, $1.25.

The original German editions of these two books were reviewed on pages 75 and 261 of our first volume.

By undertaking the translation of selected volumes of this serial of German monographs into English, Dr. J. W. Richards who has already done so much for the promotion of electrochemistry in this country, is rendering a most useful service to all interested in electrochemical progress. This series of German monographs is being prepared and edited undoubtedly with skill and with due respect to those points which are most important from an engineering and industrial point of view, and while the United States with the abundance of valuable metals is naturally leading the world in electrometallurgy, yet there are certain applications of electrochemical methods about which we can still learn from Europe. The electrolytic preparation of oxygen and hydrogen is an example. There are abroad quite a number of manufacturers of apparatus for this purpose, while we do not know of any in this country. The reason is probably that our manufacturers do not consider this a matter of sufficiently large importance; on the other hand, reports from abroad seem to indicate a continuous increase of the use of electrolytic hydrogen and of hydrogen and oxygen in the oxy-hydrogen flame for soldering and welding purposes in various metallurgical industries. It seems, indeed, quite certain that the influence of electrochemical methods and products will make itself more and more felt in the near future in the most unexpected quarters of engineering. For all who are not electrochemists themselves, but who want to apply a method of an electrochemical nature for a certain purpose, these monographs, each dealing with a distinct limited subject, should be most valuable. Finally, we quite agree with the translator, that electrochemists will find these monographs rich in suggestions of ways and means for accomplishing difficult ends, so that they are of far greater value than mere codes of operations for producing hydrogen and oxygen, and for making chromium and chromium compounds with the aid of the electric current.

Jahrbuch der Electrochemie, Berichte über die Fortschritte des Jahres, 1902. Edited by Dr. Heinrich Danneel. Halle: Wilhelm Knapp, 1904. 750 pages, price, marks 24.00.

This is the ninth annual appearance of this indispensable volume, and the work done on it is more thorough than ever before. It is the fault of the reviewer, for which he apologizes to the publisher, that this volume was not reviewed several months ago, when first received; it is the fault of someone abroad that the review of 1902 was not published until 1904, for which delay we fear that the publisher will be the principal sufferer.

However, there is every reason why this volume should share in full measure the popularity and sale of its predecessors. The author has had the assistance of Doctors Askenasy, Borchers, Elbs, Harms, Mugdan, Sackur and engineer von Kügelchen, of which the latter is now an American. The division of the subect is logical and satisfactory, the working out of each section thorough, the literature, compilation complete, and the indices above criticism. Altogether, one can feel assured that in this volume is to be found a record of every published article on electrochemistry which appeared during 1902, carefully and intelligently abstracted.

PYROMETERS SUITABLE FOR METALLURGICAL WORK.

(*Continued from page 472.*)

4. *The Roberts-Austen Recording Electric Pyrometer* (made by Messrs. James Pitkin & Co.)—This instrument, which is of the recording electrical type, was devised by the late Sir William Roberts-Austen for the continuous registration of very high temperatures, and it is widely used for recording the temperature of the hot blast and for regulating the heat of metallurgical furnaces. The apparatus consists of two mahogany cases impervious to light, the larger of which contains a Holden d'Arsonval dead-beat galvanometer, with a suitable arrangement of lenses and mirrors. The other case contains a drum which is made to revolve by clockwork once in 24, 12 or 6 hours. The surface of this drum may be covered with sensitized photographic paper. A ray of light, either from a gas jet or from a lamp, is thrown by means of a mirror at an angle of 45° on to the mirror of the galvanometer, and is projected thence to the surface of the drum, acting photographically on the sensitized paper.

The galvanometer is then connected by copper leads to a thermo-junction inserted in the space or object, the temperature of which it is desired to record. The thermo-junction may, for example, be placed in a hot blast main or in the midst of a small mass of metal which is either being cooled from a

high temperature or is being raised to a temperature below that of the melting-point of platinum. The heating of the thermo-junction causes a very small current to pass through the coil of the galvanometer, which is deflected, and the mirror attached to it projects a spot of light on the surface of the drum. The amplitude of this deflection indicates the temperature, and a continuous curve is traced on the photographic paper, which at once indicates what temperature is attained at any particular moment. A scale is also provided on which the temperatures can be read from time to time, without interfering in any way with the record. The most simple of the standard forms (pattern 1) is provided with a switch or handle, by means of which a record from any one of six furnaces or centers of heat may be obtained. The time devoted to the record of any of the six depends upon the length of time the handle is left at a definite part of the switch. The number of the particular furnace under examination is automatically registered on the drum. The second form of the instrument (pattern 2) enables two continuous and simultaneous records to be taken on the same drum from two furnaces, provision being made for distinguishing the curves. The change from one furnace to another is made automatically by means of clockwork. The third form (pattern 3) is for taking three continuous and simultaneous records.

Thermo-junctions have been used from time to time since 1826, when Becquerel advocated their adoption. Confidence in their indications was, however, only established when it became possible to obtain a good dead-beat galvanometer. The particular thermo-junctions to be used will vary with circumstances, and for many purposes the platinum-*iridium* junction, first used by Prof. Tate in 1873, possesses many advantages over other thermo-junctions. Specially designed electric recording pyrometers are also constructed by the same makers for research work, similar to those used at the Royal Mint, where extreme accuracy is required in determining temperatures. In this pattern two galvanometers are employed, one of greater sensitiveness than the other, in a case impervious to light. A ray of light either from a gas jet or from a lamp is thrown, by means of a mirror at 45° (having been focussed by suitable lenses), on to the galvanometer mirrors, and is projected thence on to the surface of a photographic plate. This plate is raised at any desired speed by means of an accurately constructed clockwork train, and the rays of light from the galvanometer mirrors, reduced by means of a horizontal slot to mere points of light, fall on to the sensitized surface, which, being developed, gives an accurate record of the temperature at every instant of time. A dark slide or plate carrier is provided for enclosing the plate, to enable it to be removed to the dark room for development.

(*To be concluded.*)

THE ELECTRIC PRODUCTION OF OZONE AND STERILIZATION OF WATER BY OZONE.

Besides electric furnace processes and electrolytic processes, a third method of producing chemical effects by means of electricity has attracted considerable attention in recent years. These are the effects produced in gases by electric discharges through the same. There is considerable difference between different processes of this kind, according to the nature of the discharge required for the special purpose. For instance, for the fixation of atmospheric nitrogen it is necessary to produce arcs, while in the production of ozone from atmospheric oxygen, silent electric discharges are utilized and arcs must be avoided.

A summary of the different processes for making ozone by electric discharges through air, and for the subsequent use of ozone for the sterilization of water, was given on pages 65 an d426 of our present volume, where references to various descriptions of apparatus of this kind may also be found.

Among ozonizers, that of A. VOSMAER, a Dutch electrochemist, should be of special interest at present, for two reasons: Firstly, because no solid dielectric is used, so that there is no danger of breakage of glass, etc. Secondly, because this process is to be introduced in the United States by the United Water Improvement Co., of Philadelphia, Pa., who have acquired the American rights of this system. This company has recently published a very full report by Mr. J. J. DE KINDER, who has made a full investigation of the process in Holland. From this report the following information is taken.

The plant using the Vosmaer process is located at Nieuwersluis on the River Vecht, between the cities of Amsterdam and Utrecht. This river is one of the most polluted waters in Holland. The water-ozonizing capacity of the plant is equal to 20 cubic meters per hour, or, in round numbers, 5300 gallons.

The water to be ozonized is conveyed by means of a pump from the Vecht to a Kronke rough filter, and from there to the top of a standpipe, having a diameter of 15 inches and a height of 35 feet, down which standpipe it flows on its way to the receiving reservoir located outside of the building.

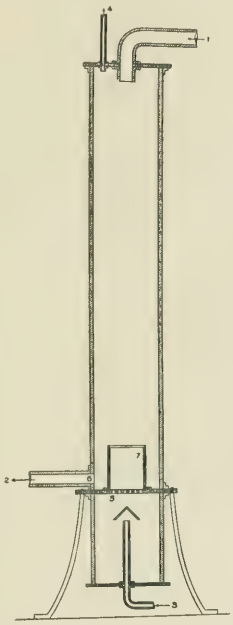


FIG. 1.—STERILIZER.

Air is drawn by means of an air pump from an iron tank, in which are shelves with chloride of calcium, and issues from the tank in a dry condition, the chloride of calcium having absorbed the moisture which it contained before entering the tank.

On its way to the suction side of the pump the air passes through the ozonizer, an apparatus consisting of a number of light copper tubes, each about three inches in diameter and 16 feet in length, the tubes being supported at either ends in headers in the manner of an ordinary closed feed-water heater), the air discharge pipe from the drying tank connecting with the header at one end of the ozonizer, and the air suction pipe to the air pump with the opposite header of the ozonizer. The pump compresses the air to slightly above atmospheric pressure and delivers it in the bottom of the standpipe already referred to, in which it ascends, distributing itself in minute globules through the descending water.

From one and one-half to two grams of ozone per cubic meter of water pumped are used; one kilowatt-hour of electrical energy produces 15 grams of ozone; the quantity of ozonized air required for the ozonizing of the water is in proportion of about one and eight-tenths volumes of atmospheric air to one volume of water.

The general arrangement of the sterilizer is shown in Fig. 1. The water enters at 1 and passes out at 2, while the ozone enters underneath at 3 and passes out at 4, the ozone having completed its work and having again been changed to oxygen. The apparatus works continuously and entirely on the counter-current principle, which is naturally the most economical. A peculiar construction of the lower part, shown in Fig. 1, makes it impossible for the water to enter into the ozone supply, and prevents the ozone from passing out with the water. The first is obtained by the presence of the perforated plate 5. As long as there is sufficient pressure, water can-

not possibly pass, on the principle of the bottom of a Bessemer converter. The second is obtained by the presence of the perforated wall 6 and the screen 7.

A large amount of information is given on the results obtained in extensive tests of ozone-sterilization of water. The conclusions reached by Dr. Ohlmueller and Dr. Prall, of the German Imperial Board of Health, are specially noteworthy, and are given as follows: By the treatment of water with ozone a remarkable destruction of bacteria is produced, and in this regard ozonizing is in general superior to separation

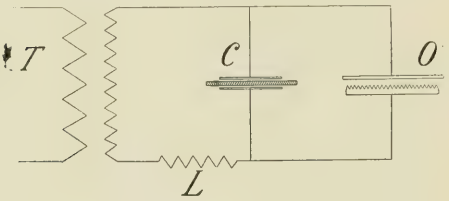


FIG. 2.—CONNECTIONS FOR PREVENTING ARCS.

of bacteria by sand filtration. The cholera and typhus bacilli are destroyed. Viewed from a chemical point of view, the water is affected only in so far that the oxidability is reduced and free oxygen increased, both of which mean an improvement of the water. The ozone which is introduced in the water is of no importance from a technical or health-affecting consideration, as it readily changes into oxygen. The treatment of it improves the water by making it colorless. The taste is not affected, etc.

Mr. Vosmaer claims his plant to require a minimum of attendance, and that it is practically self-operative. During the entire tests the only attention required was the keeping of steam to workable pressure, and examining once a day the oil cups on the movable parts of the pumps, etc.. In other words, the plant practically ran itself.

The main point of interest for electrochemists is the production of ozone by silent discharges through atmospheric air. It has long been known that the chief point to be taken care of is the prevention of sparks or arcs. It is only the silent or brush discharge which causes the oxygen of the air to be changed to ozone. Most other systems take recourse to solid dielectric, glass being generally used; this is, for instance, the case in the ozonizer of Siemens and Halske. The danger is here that the glass, becoming heated, turns to slightly conduct the electricity, and a destructive spark is then liable to result.

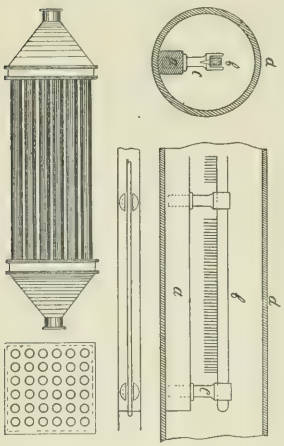


FIG. 3.—DETAILS OF CONSTRUCTION OF OZONIZER.

In the Vosmaer system there are no solid dielectrics between the points of discharge, neither high frequency nor high resistances nor rotating electrodes, but the brush discharge is produced by using sharp-pointed discharges against flat electrodes and the voltaic arc, by special way of connecting up, is absolutely prevented. In Fig. 2, T is an ordinary step-up transformer, C is a high-tension condenser, L is a high-tension choking coil, and O is the ozonizing apparatus. The high-tension alternating current from T is shunted by the condenser, while the choking coil is in series with the line. In this way an arc discharge at O is made impossible.

The ozonizing apparatus per se is simplicity itself. There are no moving parts; no fragile material is employed and no cooling whatever is resorted to. The ozonizer consists of a number of tubes put together something like a feed-water heater, as shown in Fig. 3. In each tube, *d*, there is a complete set of dischargers, viz: one flat, *a*, and one pointed, *b*, separated from each other at a fixed distance by insulated stems and forks, *c* (made of porcelain). There is nothing out of the ordinary about the transformer or choking coil, but the condenser is of special manufacture. Its general outline is shown in Fig. 4, and if made with care it never gives rise to any trouble.

Fig. 5 shows the general arrangement of all the apparatus. FI means the rough filter from which the water, by means of the pump WP, goes to the top of the sterilizer ST and leaves by the valve V. The air enters through the air-dryer AD, goes through the ozonizer OZ, and by means of the pump OP is forced into the bottom of sterilizer ST.

An ordinary generator DY delivers alternating current to a switchboard SW, from whence it goes to the step-up transformer TR (earthed), and from here to the ozonizer OZ (earthed).

When once properly started the plant requires hardly any attention. The only question of importance is the determination of the amount of ozone required for the particular water to be treated. There are two methods for determining whether the quantity of ozone supplied be sufficient or not. First, by testing the surplus of ozone at the outlet of tube 4 in Fig. 1, by iodine of starch paper. Second, by the sense of smell. As long as there is ozone left it is certain that there

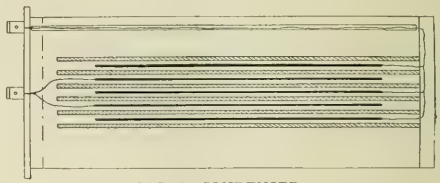


FIG. 4.—CONDENSER.

has been sufficient to destroy the bacteria, and if more absolute certainty is desired, there is still another way, viz: determining by chemical means the quantity of soluble organic matter oxidized. Experience, however, is a safe guide, and there is no special skill required at Nieuwersluis to run the plant. Any engineer of ordinary intelligence can do so.

The main conclusions reached by Mr. de Kinder are: "First, that filtration alone can, in addition to clarifying water, effect purification of the same, only to a degree varying with construction, maintenance, supervision, etc., of the plant; and, secondly, that by ozonizing a previously clarified water absolute purity if obtained." Hence, the belief is expressed that "as an adjunct to any filtration system, sufficiently efficient to produce clear water, sterilization by ozone will prove to be one of the greatest blessings of this century."

An experimental plant, using the Vosmaer system, is now being erected by the United Water Improvement Co. on the Schuylkill, near Philadelphia. The building is almost finished, as is most of the machinery, and it is expected that it will be in running order at the beginning of December. At this plant, polluted water will be taken from the Schuylkill, at a point below the intercepting sewer and below the slaughter-houses and manure yards. A million gallons of water are to be treated per day; they are to be first passed through a rough filter and then subjected to the Vosmaer system of ozone sterilization.

THE WORKS OF THE POWER AND MINING MACHINERY COMPANY.

The plant of the Power & Mining Machinery Co., at Cudahy, Wis., has been designed so as to embody all the latest developments and achievements of shop management and operation. As it stands, it has all the modern labor-saving devices that could be adopted. The buildings are arranged with reference to each other, so that there shall be the least handling of material, and the arrangement of machinery in it has been carried out with the same idea uppermost. Where it is necessary to handle material, the latest devices, usually overhead cranes, are installed.

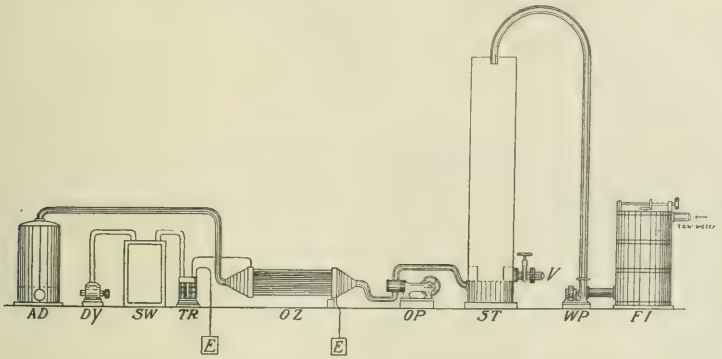


FIG. 5. GENERAL ARRANGEMENT OF PLANT FOR STERILIZING WATER BY OZONE

The plant was designed for the construction of Loomis-Pettibone gas apparatus, American Crossley gas engines, and mining machinery. Its most novel feature is probably the power house. This consists of products of the plant itself, namely, Loomis-Pettibone gas producers furnishing a supply of gas for operating the American Crossley gas engines, direct connected to General Electric dynamos. Water gas is also generated for use in forges and furnaces.

In the construction of the buildings, the question of light and ventilation was given special attention. Connecting the buildings is a net-work of railway tracks, which greatly facilitate the handling of material. In the separate buildings these run under the crane ways so that the cranes may lift the heavy parts from the cars and set them where desired.

The office building is occupied by the offices of the plant, the private telephone exchange and the engineering department, with a drawing room. Immediately to the rear of this building is the machine shop, which is the largest of the group of buildings. The total length is 552 feet, its greatest width 162 feet. The shop is fully equipped with modern machinery. In the selection of the machines, special effort was made to obtain those necessitating a minimum amount of chucking. All are driven by General Electric motors. Where convenient, line shafting has been erected, and one motor operates a group of several machines. In such cases, to economize space, the motor is placed overhead. The larger machines, however, are driven separately. Sometimes the motors are geared to the machines direct. Often belts and counter shafts are employed.

Buildings nearby situated contain the forge room, the sheet metal shop, the pattern shop, the pattern storage building and the foundry. The foundry is equipped with a large cupola furnace with draft by a Connersville Blower Company blower, electrically driven. Iron and fuel is conveyed to the furnace by means of the railway along the south side of the foundry, and is raised to the charging floor by means of a motor-driven elevator. The foundry is supplied with three overhead cranes, which serve the entire floor. The two on the main craneway have a span of 65 feet, and are 30 and 15 tons capacity. The larger is provided with a 5-ton auxiliary hoist. An 8-ton crane with a span of 40 feet, serves the remainder of the foundry. Casting weighing 50 tons have been poured in the foundry. Two large ovens are built into this foundry near the southeast corner. A small lean-to at the northeast corner contains the rattlers. For blowing out molds, running molding-machines and shipping castings, compressed air pipes are dropped down posts at convenient points. To steady the supply of air piped from the power house, a storage tank is placed in the foundry.

THE POWER PLANT.

The power plant, which furnishes a working exhibit of the products manufactured by the company, is located in an L-shaped brick building in the extreme northwest corner of the yard. The extension on the south contains the Loomis-Pettibone gas producers, boilers, controlling mechanism and coal-handling apparatus. The eastern extension is occupied by the American Crossley gas engines, generators and switchboards and a gas engine driven air compressor. At the juncture of the two extensions is a room containing the scrubbers, exhausters, feed-water heater and a small auxiliary boiler. The gas holders, cooling basin and dry scrubber are located in the angle between the two portions of the building.

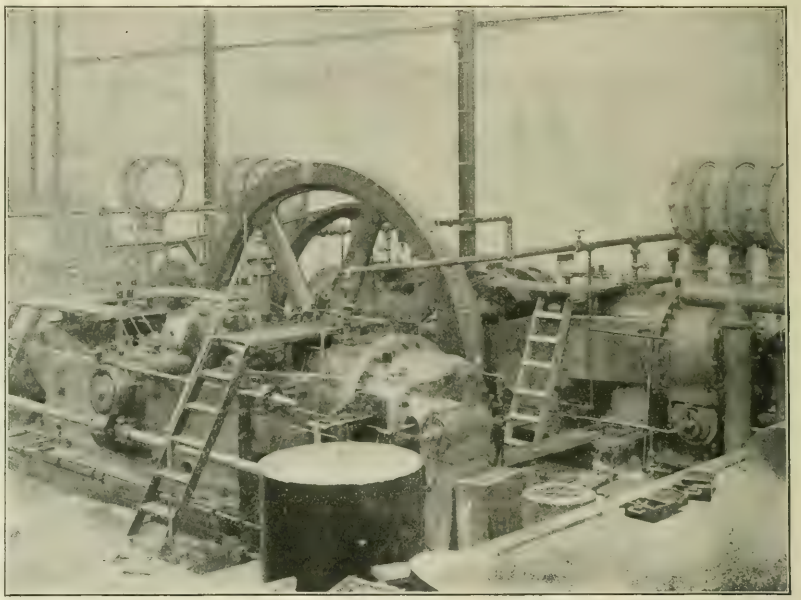
Either producer or water gases are generated from the same apparatus. A portion is piped direct to the engines in the generator room, and pipes are also laid to the furnaces of the forge and boiler shops, and to the testing floor in the machine shop. The wing containing the producer is provided with an intermediate or operating floor.

Four producers, having a total capacity of 2000 hp., are provided. These are divided into two generating sets. Two producers operate in connection with one boiler and form a set. The two sets may be operated independently. Each producer measures 9 x 15 feet, and is connected near the base through a 30-inch valve provided with hydraulic control to the boiler operating with it. The boilers, which measure 5 x 23 feet, are set vertically, and are designated much after the pattern of an ordinary fire-tube boiler, the hot gases from the producer passing through the tubes. Leading from each boiler are two gas mains, that for the producer gas being 24 inches, while the other, for water gas, is 20 inches in diameter. The mains from each of the boilers lead to the bottoms of one of the two wet scrubbers located in the corner room. A main leads from the top of the producer gas scrubber through the engine-driven exhauster. The discharge from the exhauster is 20 inches, and, according to the position of the controlling valve, leads either to a purge stack exhausting into the atmosphere, or to the dry scrubber located outside the building. A by-pass, which may be used as occasion may require, is provided around this scrubber. A short length of 20-inch main connects the dry scrubber to the producer gas holder which is of 10,000 cubic feet capacity. From the top of the water gas scrubber a 16-inch main goes direct to the water gas holder of the same capacity as that for producer gas.

The gas from the producers in passing through the boiler on its way to the scrubbers, generates steam which is used for several purposes. In making water gas, it is introduced direct into the bottom of one of the producers. A limited quantity is also supplied above the fires of the producer, when producer gas is being generated. A 2-inch steam pipe leads to the en-

gine operating the exhauster. The boiler feed pump working in connection with the feed-water heater, as well as the pump supplying pressure for the hydraulic valves, are also operated by steam.

A 6-inch water main from the water system of the plant enters the power house; a 2½-inch pipe is tapped from this and leads direct to the water-cooled valves between the generators and the boilers. Another branch passes to the 6 x 4 x 6 inch pump maintaining pressure for operating the hydraulic valves. Water is also supplied to two circulating systems of cooling water. One of these extends between the cooling basin and the scrubbers in which the gas is cooled and cleansed. A direct-connected electrically driven pump located near the west wall of the engine room discharges through a 4-inch pipe leading to the top of the two scrubbers into which the water is thrown, in the form of a spray. The water having fallen down over the layers of coke in the scrubber, it flows out of the bottom of the scrubbers to the western end of the cooling basin, and after its temperature is reduced, it is again pumped through the circuit. A similar pump, also motor-driven and placed near the scrubber pump, circulates water through the jackets of the engines. A 6-inch discharge from the pump runs the full length of the engine room, taps leading to the water jackets of the engine being taken off at frequent intervals. The discharge pipe continues through the engine room and to the testing floor in the machine shop. The returns from the jackets pass to the eastern end of the cooling basin shown in the engraving. The two portions of the basin are divided by a solid partition to prevent the mixing of the water of the two circulating systems.



1400-HP. GAS ENGINE

To start the plant when cold, the producers are filled with coal to a depth of about 5 feet. This is lighted at the top. The exhauster is then started, steam from the engine being obtained from the auxiliary boiler. The down draft produced by the exhauster soon ignites the mass of coal. More fuel is then added until the bed is about 8 feet thick. While the fire is getting under way, the gas being of an inferior quality, is allowed to pass off into the atmosphere through the purge stack mentioned. After the fires have assumed the proper heat, the purge stack is closed, a limited quantity of steam is admitted above the fires, and the producer gas generated is exhausted into the holder. If desired, producer gas may be made continually, but usually the requirements of the furnaces and forges are such that the generation of producer and water gases is alternated at periods of from 10 to 20 minutes. To make water gas, a few changes are necessary. The charging doors of the producers are screwed down tightly. The water gas scrubber is connected with the boiler and the connection with the producer gas scrubber closed by the operation of hydraulic valves. The 30-inch valve between the boiler and the bottom of one of the producers is also closed. Steam is then admitted to the bottom of the producer, whose connection with the boiler has been closed. The pressure forces it up through the fire of the producer, through a pipe connecting the two producers at the top and down through the live coals of the other producer. It then passes as gas through the boiler and scrubber to the gas holder.

The steam soon cools the fires to a point at which they do not decompose the steam. The proper valves are then opened and closed and producer gas is generated until the fuel is brought to incandescence. When water gas is again generated, steam is introduced into the second producer, and its path through the two producers is thereby reversed. This enables the raw steam to come in contact with the fire least cooled by the previous operation. As stated before, two producer sets are installed. One is run until the ash or clinker in the producer limits its capacity. The other set is then fired, the scrubber connection to the old set being closed. By means of the cleaning doors at the grate level, the old producers are then emptied and cleaned, when they are again filled and are ready to be fired. About 80 tons of bituminous coal can be consumed before cleaning is necessary.

The engine room is to contain three 22 x 30 inch two-cylinder American Crossley gas engines, each direct connected to a 150-kw., 250-volt, direct-current generator. A smaller engine of the same general design will operate an air compressor supplying air to the surrounding shops. Gas for the engines will be supplied through a 20-inch main. The connections are such that either all water gas, all producer gas or any desirable mixture of the two may be supplied to the engines.

The leads from the dynamos will be run through vitrified clay conduits under the cement floor to the switchboard located along the eastern wall of the engine room. This contains three generator panels and several feeder panels through which are distributed the sixteen lighting and power circuits leading to the several shops. In all, about 50 motors, varying in size from 50 to 3 hp., are employed. The greater of these

are of about 28 to 30 hp. The power load is about 66 per cent of the total, the remainder being consumed in the 250 arc lamps used in lighting the shops.

GAS ENGINES.

The American Crossley gas engines, manufactured by the company, are made with single cylinders up to 150 hp. Two cylinder engines range in power from 180 to 645 hp., while those of four cylinders are rated at from 360 to 1400 hp. and larger. The engines are assembled and tested in the western portion of the machine shop.

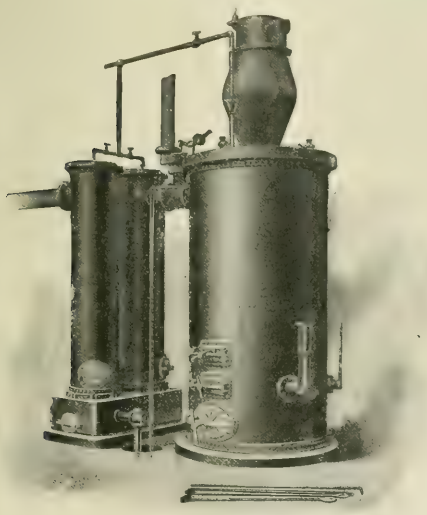
In one of the views, a four cylinder engine is shown on the test blocks. This was built for the Elmira Water, Light & Railway Co., of Elmira, N. Y., and will be direct connected to the generator. The engine is rated at 1400 hp., and has a 36-inch stroke, the cylinder diameter being 32 inches. A flywheel 13 feet in diameter is provided. A notable feature of the engine is the method of constructing the water jacket. The inner metal surrounding the combustion chamber is cast separate from the outer. Lugs are cast on the outer and inner walls of the two shells. These are drilled and tapped, and binding stays inserted, which tie the shells together. This method of construction is used in order that casting strains, blow-holes and other defects may be avoided.

Each cylinder is fitted with a weighted fly ball governor, which varies the mixture in the cylinder according to the load carried. A safety gear prevents the engine starting in the wrong direction. Ignition is accomplished by a double ignition tube arranged so one tube may be renewed while the engine is operating. The entire oiling system drains to the crank pit. The engine is built under a guarantee of speed variation not to exceed 2 per cent from the mean.

A SUCTION PRODUCER.

Another of the products of the plant is shown erected in the machine shop. This is a 100-hp. Crossley suction gas producer.

The producer proper consists of a cylindrical shell lined

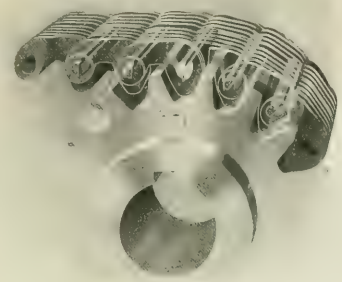


SUCTION GAS PRODUCER.

with fire brick and fitted with a revolving grate. The gas, after passing to the top of the producer, enters an evaporation, where heat is transferred from the gas to water forming steam, which enters the bottom of the producer. A hydraulic box, through which the gas next passes, prevents the gas backing up into the producer. It then flows through a coke scrubber, where it is cooled and cleaned, and then through one of sawdust, to remove any fine ash or other solid matter which may have been drawn through from the producer.

THE SILENT CHAIN FOR DRIVING MACHINERY.

The introduction of the silent chain drive has broadened the field for motor driving, which is now of such importance in



SILENT CHAIN CONSTRUCTION.

any shop management. The silent chain has all the advantages of flexibility and smoothness of drive, inherent in the belt drive, and to this is added the positiveness of drive which belongs to gearing.

The Morse Chain Company, Trumansburg, N. Y., has made a special study of the application of silent chain driving to severe and limiting conditions, which have given trouble with any other method of driving. As a result, they have perfected a chain for machinery driving which is adaptable to any class of service whatever; it is not affected by high-speed, very hot or dry atmosphere, or moisture, and will run satisfactorily with but little lubrication. It is found in practice to not wear rapidly even when subjected to the most severe extremes of dust, dirt and grit imaginable. The important feature is that its efficiency in transmission of power is very high, being by actual test from 98½ to 99 per cent.

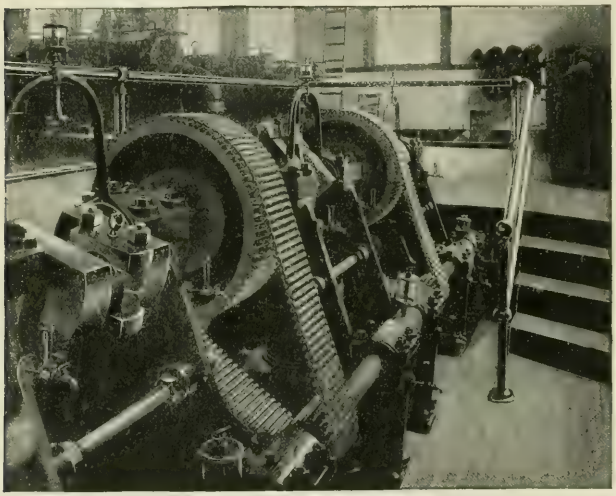
The accompanying illustration of two chain drives, operating from a motor-driven shaft to drive condensing pumps, shows the use of the positive and noiseless drive under conditions where a belt could not possibly be used. These chains were introduced here to replace the gears formerly used, on account of their noisy action. The maximum pull on the chain is 10,000 pounds, which alternates to 300 pounds negative pull at each stroke, due to the intermittent action of the pumps, but over two years' service shows no depreciation.

Concerning the construction of the chain drive the following remarks may be made. The joint consists of two pieces of hardened tool steel, so shaped and arranged that, as the joint works while passing on and off the sprockets, one piece rocks or rolls on the other. The two rocking parts of the joint are fixed in opposite ends of the links, and as there is only a pure rolling friction on hardened tool steel surfaces with ample contact area to withstand the pressure, there is no tendency for the joint to wear and cause the chain to lengthen. To prevent undue vibration under high speeds and the consequent wear, the rocker pins of the high-speed silent running chain are so shaped that the areas of contact surface are greatly increased when the chain is drawn straight between sprockets, in which position a broad bearing is given. Th-

two-part pin used in the Morse rocker joint permits of an unbroken contact the whole width of the chain, less the outside links, which results in nearly doubling the length of the bearing surface over a chain with a single-pin joint.

As the rocker joint is subjected only to rolling friction it does not require lubrication, and the speed limit is therefore not fixed by the point at which the centrifugal force will throw off the lubricant. A paste grease, sufficiently heavy so that it will not be thrown off at high speeds, affords proper lubrication for the chain in its contact with the sprocket teeth and between the plates of the chain itself. As the pressure between the chain and the sprocket teeth is inversely proportional to the number of teeth in contact with the chain, and as this number is large, the pressure is small, and very little wear will take place.

With the increasing use of machine tools in all manufacturing shops, a study of this important branch of the subject will be profitable. Under shop conditions, where the question of motor-driving is simplified by the presence of



SILENT CHAIN DRIVE, APPLIED TO PUMPS

an electric power distributing system, the silent chain proves particularly applicable for machine driving. For this reason the subject should be of special interest to all metallurgical works with modern equipment.

ST. LOUIS EXPOSITION.

Owing to lack of space, we have to reserve for our next issue descriptions of several exhibits of interest to electrochemists and metallurgists, supplementary to our article in our September and previous issues.

A list of prizes awarded by the jury to exhibitors will also be given in our next issue.

INDUSTRIAL NOTES.

We have received from Mr. Hugh E. King, Chicago, Ill., a pamphlet on the Pelton electric furnace for manufacturing jewelers, assayers, chemists and the tempering or hardening of steel hubs and dies. The standard types are for both direct or alternating current at 100 to 120 volts. The furnace is a muffle furnace with a large sheet of mica in the door, which affords unobstructed view of the interior of the muffle, thus enabling the operator to observe his work.

The St. Lawrence River & Power Co. has issued an extremely handsome and nicely illustrated book, descriptive of the power plant, the town of Massena, in which it is located, and a few of the industries already using the power. Most notable among the latter is the Pittsburg Reduction Co., which has purchased a large plot of ground from the Power Co. and has already erected buildings thereon costing $1,200,000; in one of these buildings alone, 12,000 e. h. p. is used, and another contains the most modern wire-drawing and insulating plant in existence. The Pittsburgh Reduction Co. is constantly extending its plant and will eventually use 50,000 hp.

We have received from Messrs. E. H. Sargent & Co., of Chicago, their fully illustrated catalogue of chemical apparatus and assayers' materials. It is a handsomely bound volume of 238 pages, and deals with apparatus and instruments of all kinds, for use in chemical laboratories and plants, including balances, all kinds of glass apparatus, burners, cement-testing apparatus, calorimetric carbon apparatus, combustion apparatus, condensers, crucibles, desiccators, distilling apparatus, extraction apparatus, filters, all kinds of furnaces, apparatus for handling gases, platinum ware, polarization apparatus, thermometers, etc. The catalogue is conveniently arranged in alphabetical order, and fully illustrated.

A prominent engineer of the Power Mining & Machinery Co. gives the following interesting particulars concerning the economies of gas-generating plants, as compared with steam plants. The yearly records of eleven electric power stations, each serving a population of 5000 or less, and of forty-five stations, each serving 5000 or more, show:

The average B. H. P. developed, 1235.

The average coal consumption per B. H. P. hour, 5.5 lbs.

The average cost of coal per ton, $4.30.

Cost of fuel in steam plant (operating 10 hours per day), 33.96 tons coal at $4.30, $146.02.

Cost of fuel with our gas engines and producers, 7.72 tons coal at $4.30, $33.19.

Saving per day, $112.83.

Annual saving (365 days at $112.83), $41,182.95.

This would mean a saving of over 77 per cent for fuel alone, paying practically 11 per cent on the average capital invested in the above fifty-six plants. The producers of the Power & Mining Machinery Co. work on hard or soft coal, wood or coke, changes from one to the other being made without interruption.

Uses of Lava.—We have received from the American Lava Co., Chattanooga, Tenn., an interesting pamphlet on lava for mechanical and industrial purposes. Lava is not, as is frequently supposed, a natural product of volcanic origin. It is the mineral talc, which is machined in its natural condition and then baked at a temperature of about 2000° F., to a condition of extreme hardness. It is then unaffected by any subsequent temperature short of that heat, and therefore by any heat to which it may be exposed when used in the construction of arc lamps, rheostats, electric heating apparatus, etc. It fuses with difficulty under a strong blast flame and, as the pamphlet states, "has no superior in withstanding the electric arc." It is only slowly dissolved by hydrochloric acid and is not affected at all by other acids or by alkali. It is absolutely free from metal oxides or other impurities which would impair its insulating value. "It is permanent in constitution and, being a natural product, is not subject to variations in structure or composition." It neither swells nor shrinks with

changes in atmospheric moisture, and its coefficient of expansion with temperature being negligibly small, it is of especial value in instruments requiring a fixed relation of their parts under all conditions. The material before baking is sawn, milled, drilled, turned and threaded with the same freedom as brass and by tools of the same character. Concerning its electric insulation capacity, it is stated to be remarkably uniform in its ability to withstand high potentials, even better than porcelain.

The NATIONAL ELECTROLYTIC CO., Buffalo, N. Y., is reported to have purchased the plant and business of the Vermillion Chemical Co., at Niagara Falls, N. Y. for $600,000, and will continue the manufacture of electrochemical products, adding largely to the products turned out.

Dr. JULIUS KOEBIG and Mr. STEPHEN V. CHILDS have consolidated their chemical and metallurgical laboratories in Los Angeles, Cal., at 127 West First Street, where they have the best modern facilities for making tests by amalgamation, concentration and cyanide; for making chemical analyses and assays. Their establishment takes the name of the Los Angeles Chemical and Metallurgical Laboratories.

OBITUARY.

The sudden death of Dr. THOMAS M. DROWN, president of Lehigh University, will be felt by thousands of his friends and old students as a personal loss.

Thomas Messinger Drown was born March 19, 1842, and was educated at the Philadelphia Central High School, where he graduated in 1859. He then took up the study of medicine and three years later received the degree of M. D. from the University of Pennsylvania. After a brief period of practice as a physician, he turned to chemistry as his life work, and studied under Professors Brush and Johnson at Yale and under Professor Gibbs at Harvard. Three years were spent in Germany in the study of chemistry and metallurgy, partly at the School of Mines at Freiberg, and partly under Professor Bunsen at Heidelberg. He subsequently established himself as an analytical chemist at Philadelphia, and removed in 1874 to Easton, Pa., to become Professor of Chemistry at Lafayette College, where he remained for seven years. In 1873 he was elected secretary of the American Institute of Mining Engineers, and retained that position by unanimous re-election until he resigned it in 1883.

An episode from this period of his life characterizes the man, who, in a critical moment, when things were to be done, knew what to do. In June, 1879, Pardee Hall, of Lafayette College, then containing the office of the secretary, and the library and other possessions of the institute, was destroyed by fire. It was impossible to save much, so Dr. Drown immediately decided to sacrifice his own technical library and to save the records of the Institute and the stock of back volumes of the Transactions. In this he was successful.

In 1885 he accepted the professorship of chemistry at the Massachusetts Institute of Technology, where he built up a large and successful department, including, at the time of his resignation, twenty-one instructors and five hundred students. From 1887 to 1895 he was in charge of the chemical department of the investigation of the natural waters of Massachusetts. In 1890 he was appointed a member of the international committee to devise standard methods for the chemical analysis of iron and steel. He was elected an honorary member of the Institute of Mining Engineers, and in 1897 its president.

In the spring of 1895 Dr. Drown was elected president of Lehigh University, and on June 19th of that year he was inaugurated. How successful his administration has been for nearly ten years is a matter of common knowledge. He died suddenly, on November 16, from the effects of a surgical operation.

PERSONAL.

Dr. CHARLES BASKERVILLE, the new head of the department of chemistry in the College of the City of New York, has been presented with a loving cup, designed by Tiffany & Co., by his former colleagues and students at the University of North Carolina, on the occasion of the tenth anniversary of his doctorate.

According to a note of Mr. R. Pitaval in the *Journal de l'Electrolyse*, the Committee of Chemical Arts of the Société d'Encouragement pour l'Industrie Nationale has decided to grant the grand Lavoisier medal to Mr. P. L. T. HEROULT, the distinguished electrometallurgist of aluminium and iron and steel. The Society grants this medal every seven years to that inventor whose work has exercised the greatest influence on the progress of the French industries in the field of chemical arts during the past six years. The former Lavoisier medalists are Messrs. Osmond (1897), Solvay (1891) and Michel Perret (1885).

Mr. NEWCOMB CARLETON has been appointed fourth vice-president of the Westinghouse Electric & Mfg. Co. Mr. CARLTON was director of works at the Pan-American Exposition, and afterward vice-president of the Bell Telephone Company, of Buffalo. He will now have headquarters in the executive offices of the company at 120 Broadway, New York city. Mr. L. A. OSBORNE, formerly fourth vice-president of the company, has been promoted to the office of third vice-president, made vacant by the resignation of Mr. PH. FERD. KOBBE, who has retired from his more active duties on account of ill health. Mr. Kobbe will continue his membership on the board of directors, and the company will still have the advantage of his counsellorship in this capacity.

DIGEST OF U. S. PATENTS

PRIOR TO JULY, 1902.

Compiled by Byrnes & Townsend, Patent Lawyers, National Union Building, Washington, D. C.

MOLTEN ELECTROLYTES, MISCELLANEOUS.

(*Continued from page* 474.)

507,374, October 24, 1893, F. M. Lyte, London, England.

A carbon electrode having a central bore filled with fusible metal, e. g., lead or tin, into which depends a terminal of copper or of iron coated with lead.

510,276, December 5, 1893, F. M. Lyte, London, England.

A cell for electrolyzing molten lead chloride, consisting of a pot of cast or wrought iron, and a bell of earthenware or plumbago, which depends into a layer of molten lead, serving as cathode, in the bottom of the pot. The space between the upper part of the pot and the bell is filled with powdered charcoal or sand, resting on the lead. A siphon tap for the lead extends through the side of the pot. Carbon anodes of the construction shown in the preceding patent, extend through the top of the bell, tight joints being made by means of asbestos string or a cement of ground asbestos and a sodium silicate. The bell has a feed pipe which extends down into the lead chloride and a chlorine outlet. The cathode connection may be a tinned iron rod extending into the lead outside the bell, or the pot may serve as the cathode if tinned internally.

473,393, April 19, 1892, Paul L. T. Heroult, Schaffhausen, Switzerland.

An anode for the electrolysis of molten compounds, especially of aluminium, consisting of small carbon slabs of regular shape, fitted together so as to break joints and held by

transverse pins or dowels of carbon, the metal to be recovered or an alloying metal. The slabs are clamped together by metallic side plates and bands.

503,429, August 15, 1893, Farnham M. and Cecil H. M. Lyte, London, England.

Simultaneously purifies lead, recovering the silver, and produces chlorin. Lead freed from zinc is oxidized and dissolved in nitric acid. Spongy or finely divided lead is added to the solution to precipitate the silver and other metallic impurities. The lead is then precipitated as chloride, which is washed, dried, melted and electrolyzed. The cell is a vessel of earthenware or enameled iron heated in a sand bath. The electrodes are depending alternate anode and cathode plates of graphite, passing through gas-tight joints in the cover. The cover is sealed by a liquid or an asbestos gasket, and has a chlorine outlet. The metallic lead collects in the bottom of the vessel and overflows through a siphon of earthenware or iron enameled externally. The lead chloride is introduced through a sealed pipe. The molten lead may be made the cathode. The lead is precipitated from the nitrate solution by calcium or magnesium chloride. These may be obtained from the waste chloride liquors of the ammonia-soda process, *e. g.*, a liquor containing calcium and sodium chloride may be concentrated by boiling and the sodium chloride crystallized out by cooling. Any lead retained in the residual calcium nitrate solution is precipitated by milk of lime, lead hydrate, magnesia or caustic soda. The calcium nitrate is evaporated to dryness and decomposed to recover the nitric acid. Magnesium chloride produced by treating magnesia with calcium chloride and carbon dioxide may be employed as a precipitant. The resulting magnesium nitrate is reburned to give nitric acid in magnesia.

531,309, December 25, 1894, Alfred Guillaume, Chicago, Ill.

Ores containing, *e. g.*, lead, copper, zinc and silver are smelted by an electric arc, the temperature of the arc being gradually raised to remove the metals in succession, beginning with that of lowest melting point. The smelting furnace is a horizontal chamber with electrodes extending through the ends, the cathode being a bent, water-cooled carbon tube.

The temperature of the arc is regulated by a rheostat. The slag flows through a tap-hole onto a frusto-conical rotating horizontal drum cathode, cooled by water flowing through it. The metallic deposit is removed from the drum by a scraper. The electrolyzing current flows from the positive electrode of the smelting furnace through the slag to this cathode, but a separate anode may be employed. When gold or silver is to be electrodeposited on the drum, it is formed of an alloy of 95 copper and 5 aluminium; for the baser metals, of 95 steel and 5 aluminium.

537,005, April 9, 1895, George D. Burton, Boston, Mass.

Sulphide ores of gold and silver are smelted by carrying lumps of the ore down an inclined metal-plate cathode in a stream of an aqueous solution of sodium carbonate and borax, or cream of tarter and sodium chloride. The solution is pumped onto the higher end of the plate by a metallic bucket-wheel, serving as the anode. The ore is smelted by arcs formed around the lumps, a current of 100 to 300 amperes at 500 to 1000 volts being employed. The cathode plate rests on a hearth of firebrick. The molten products run from the lower end of the hearth through a screen into a water tank, from which the metals are recovered as globules. The cathode plate may be of lead, copper or iron.

559,729, May 5, 1896, Richard O. Lorenz, Gottingen, Germany.

Produces zinc and lead by leaching ores and waste with acetic acid to remove lead and silver, and with hydrochloric acid to remove zinc. Converts the lead and silver into chlorides. The zinc lyes are purified, evaporated to dryness, melted and electrolyzed. The cell is an inclined retort-like vessel of iron lined and coated with fire-clay. It has a clay cover with a gas-outlet and a tap-hole below. The carbon-rod anodes and cathodes pass through the cover. The electrolysis is so conducted as to secure a frictional separation of the metals, silver being first deposited mixed with a certain proportion of lead, followed by lead and zinc. During the separation of the lead the potential difference is maintained at 0.4 to 0.5 volt, and during the separation of the zinc at 0.8 volt. Various substances may be added to modify as desired the melting point of the bath. The evolved chlorine is converted into hydrochloric acid by the joint action of carbon and steam at low red heat.

582,923, May 18, 1897, Alfred E. Hunt, Pittsburg, Pa.

A fusion pot, more particularly intended for the production of aluminium and designed to prevent accidents in cases where a large number of cells are connected in series. The pot is of the usual construction and constitutes the cathode, the anodes consisting of depending carbon rods. The bottom plate of the pot is extended outwardly to form a platform upon which the workman may stand while manipulating the anodes. This platform being at the same electrical potential as the pot itself, and the fall of potential between the anode and cathode of a single pot being but slight, there is no possibility of a serious shock to the workman.

587,830, Leon P. Hulin, Modane, France.

Compounds of the character of pumbates, chromates, antimoniates, etc., are produced by the oxidation of metallic alloys. Lead, chromium, antimony, bismuth or manganese is alloyed with an alkali or alkali earth metal by fused bath electrolysis, and the alloy heated to dull red in contact with air, thereby forming the peroxide of the heavy metal and the protoxide of the alkali metal; the oxidized products are continuously removed and insoluble peroxide recovered by digestion in water. Specifically, electro-deposits sodium from sodium chloride into lead cathode, circulates the alloy to the point of oxidation, and returns the impoverished alloy to the electrodepositing crucible.

591,355, October 5, 1897, Henri Moissan, Paris, France.

Cast titanium, consisting of metallic titanium with two to six per cent of carbon, 96 parts to an arc of 1000—2000 amperes at 60—70 volts in a carbon crucible. The carbon may be in part removed by remelting the product with titanic oxide in an arc of the same character. If a greater proportion of carbon is used in the mixture, the product is titanium carbide, TiC, ($TiO_2 + 3C = TiC + 2CO$) a crystalline carbide having the color of galena and a specific gravity of 4.3. Titanium alloys are produced by carrying out the first-mentioned reduction in presence of iron or nickel, these alloys being useful for the manufacture of titanium steel. Alloys may also be prepared by fusing the alloying metal in the electric furnace and gradually adding agglomerates consisting of titanium oxide, carbon and a glutinous matter.

596,458, December 28, 1897, Walter E. Inglis, Mount Vernon, New York.

Reduction of tin oxide in presence of a fused electrolyte. A non-conducting crucible is provided with a cathode of molten tin on the bottom and superposed anodes of carbon, the electrolyte being molten sodium chloride at a temperature above the volatilizing point of sodium. The crushed ore is fed upon the cathode through a central tube, and is reduced in this tube by sodium vapor distilling from the cathode. As the reduced tin accumulates it overflows through the lower portion of the body of ore into a groove in the bottom of the crucible upon the cathode basin, any sodium contained in the tin being oxidized by this contact with tin ore. An electromotive force of five volts is used. Any silica which may be present is converted into a fusible silicate which is said to overlie the metal in the groove and to be tapped out with the metal.

602,575, April 19,1898, Andrew Dickey, Niagara Falls, New York.

Aluminium reduction pots of the Hall type are provided with a tap fitted with a taper plug of wood or charcoal protected by clay from atmospheric oxidation.

DEC 19 1955

TN
1
C45
v. 2

Chemical engineering

Physical &
Applied Sci.
Serials

PLEASE DO NOT REMOVE
CARDS OR SLIPS FROM THIS POCKET

UNIVERSITY OF TORONTO LIBRARY

ENGIN STORAGE